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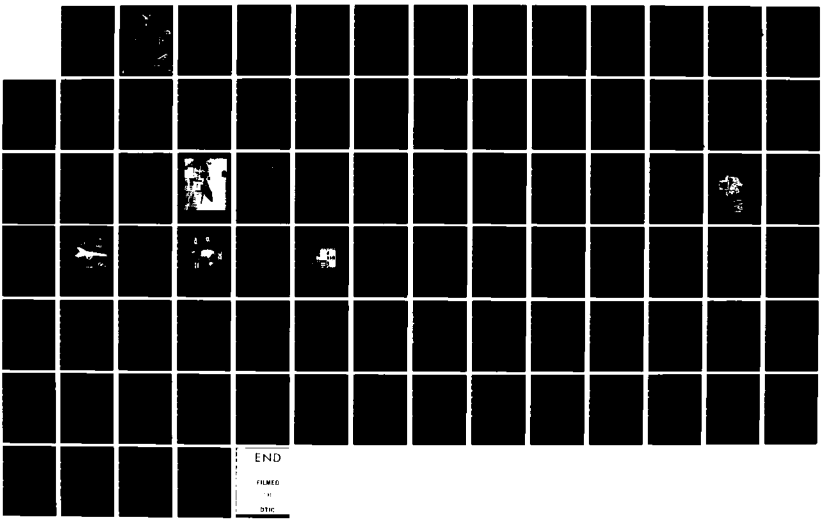

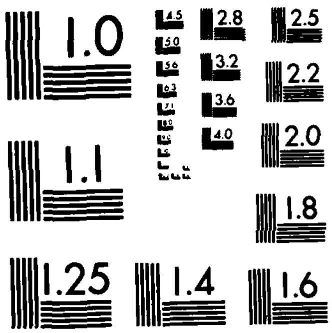


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# RPV ASSESSMENT OF REMOTE MISSILE SITE INTRUSION ALARMS

William E. Harrell, First Lieutenant, USAF
Roger K. Harris, Captain, USAF

LSSR-3-82

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This thesis addresses the question: "Can a Remotely Piloted Vehicle (RPV) effectively assess intrusion alarms at remote missile sites at a cost less than that of manned helicopter assessment?" To answer this question an RPV system was configured from existing DOD RPV subsystems. Except for wind restrictions (30 knots max.), this system was found to be capable of remote alarm assessment at a cost only slightly less than a manned UH-1N helicopter system. This proposed RPV system is not considered a viable alternative to a manned helicopter system. The cost savings using the proposed RPV system would not be sufficient to compensate for the wind restrictions and the problems associated with fielding a new system. However, once the proposed multiple vehicle control modification to the ground control station is completed, the cost savings incurred would make the proposed RPV system a viable alternative.



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RPV ASSESSMENT OF REMOTE MISSILE

SITE INTRUSION ALARMS

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Systems Management

By

William E. Harrell
First Lieutenant, USAF

And

Roger K, Harris
Captain, USAF

September 1982

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This thesis, written by

First Lieutenant William E. Harrell
and
Captain Roger K. Harris

has been accepted by the undersigned on behalf of the Faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

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# CHAPTER I

# INTRODUCTION

## Background of the Study

A missile system which has vast distances (50 miles or more) between its manned control points and launch sites will be plagued with a problem of assessing numerous intrusion alarms. High false alarm rates result from the failure of today's state of the art intrusion detectors to discriminate between threats (i.e., human vs. nonhuman) and from reliability factors due to equipment failure from normal wear and acts of God. All intrusion alarms at missile sites require a response effort to assess their significance (34:19). Consequently, intrusion alarm assessment for such a missile system is more than a trivial problem due to the number of alarms and remoteness of the sites.

A seemingly logical assessment method would be to monitor the missile sites with an infrared, closed-circuit television (IR/CCTV) system. A feasibility study was conducted by Video Teck Inc. utilizing a CCTV system installed at a Titan silo. However, the system was never made operational and the Air Force Weapons Laboratory (AFWL) does not consider it a feasible security alarm assessment method due to the expected maintenance problems and the accessibility of such a system to security compromises.

There are currently two methods utilized for security alarm assessment--manned assessment via ground transportation and manned assessment via helicopter transportation. The ground transportation

method would result in excessive response times and could be delayed by inclement weather. The helicopter transportation method would result in higher operational costs, some inclemen. weather restrictions, and a certain loss of life risk. An unexplored alternative would be alarm assessment by a remotely piloted vehicle (RPV).

Statement of the Problem

Over the years, the Minuteman security system has experienced an increasing number of security alarms. No single factor is a major contributor to the high alarm rates. However, there are four factors, when combined, that are significant:

1. Faulty equipment.
2. Sites out of adjustment/calibration.
3. Topside features generally in a degraded condition.
4. Animals (27:2-3).

This has posed an increased burden on the current manned ground transportation means of security alarm assessment resulting in excessive response times. This problem will be significantly magnified for a missile basing mode with widely dispersed silos. Also, if the present Minuteman sites were upgraded such that alarms would give a high probability of intrusion then the assessment time constraints would be more crucial (16). This, in addition to the almost certain loss of security team lives that would occur if the ground mode alarm response force encountered a trained terrorist force, would indicate a need for a quicker, more survivable means of alarm assessment.

The Nuclear Weapons Security Branch of the AFWL feels that the current ground mode of security alarm assessment is inadequate and has

requested an AFIT thesis addressing the question: "Can an RPV system effectively assess intrusion alarms at remote missile sites at a cost less than that of manned helicopter assessment?" This study will construct and analyze an RPV system capable of satisfying the alarm assessment requirements to answer the above question.

## Research Questions

The following research questions will be addressed:

1. What requirements would have to be met by an RPV system to effectively assess missile silo intrustion alarms?

2. What are the capabilities of an RPV system and a UH-1N helicopter system?

3. What are the costs of an RPV system and a UH-1N helicopter system?

4. Is an RPV system a viable alternative to a UH-1N helicopter system?

## Research Scope

The RPV system used in this study will consist of an airframe, gasoline engine, video system, guidance and control package, and a ground tracking and control station. These components will be chosen from subsystems that already exist in other developed systems. The intent is to select a configuration that will be capable of meeting the task requirements at a reasonable cost.

To avoid the necessity of having to classify this document, a hypothetical missile operation will be utilized that will allow the results of this study to be extrapolated into useful data for an actual missile operation. Some Minuteman site data will be used to ensure a meaningful scenario. The AFWL has specified that the UH-1N

helicopter be used for the manned helicopter system for comparison purposes. The authors have imposed a maximum intrusion alarm response time of 60 minutes.

### Justification

Based on the increasing security alarm rates that the Minuteman sites are experiencing, the physical distance separating the silos, and the almost certain loss of security force lives that would occur with the present method of alarm assessment should a terrorist force be encountered; a quicker, more survivable means of security alarm assessment is needed. An unmanned RPV system is one possible alternative that warrants investigation.

### RPV Development and Use

Background. An RPV is an unmanned aircraft piloted by remote control. Unlike a drone, an RPV can be controlled from a remote location once it is in operation. RPVs were extensively used throughout the Vietnam conflict with an attrition rate of less than 10%. They were used for photographic/reconnaissance, electronic listening, and other missions. There have been no civil programs that used RPVs to fulfill agency missions (35:1-3,24).

In 1971 the U.S. Air Force Flight Dynamics Lab (AFFDL) initiated project "Teleplane", to provide an in-house capability for designing, fabricating, and flight-testing low cost RPV concepts. The word "Teleplane" is a contraction for television and airplane and infers the use of miniature television cameras in small remotely controlled aircraft. Early experiments involved design and construction of several test vehicles and conduct of manv flights through the use of

video imagery. Experiments revealed that vehicle control by simple video display was a relatively easy task and could be accomplished by personnel of widely varying backgrounds and with limited training (18:16-17).

The U.S. Army is developing a miniature unmanned aircraft to locate, identify, and designate targets for its artillery. This tactical RPV is based on the Army/Lockheed Aquila system which was a technology demonstration rather than an operational vehicle development program. Aquila was developed with as much off-the-shelf hardware as feasible. There were no requirements for maintainability, reliability, or repeatability. The Army is seeking an 85% mission reliability, a 7.5 - 10.0 operating hours mean time to failure, and a 0.5 hours mean time to repair for its tactical RPV. The unit cost goals stated in the full-scale development contract are a flyaway cost of $188,000 for the air vehicle--including the vehicle, mission payload subsystem, and data link--and a unit cost of $998,500 for the complete ground support system, both expressed in Fiscal 1979 dollars 11:63).

The Department of Defense (DOD) currently has no operational RPVs and has limited plans for future applications. In 1978 Congress noted DOD's lack of success in deploying new unmanned vehicles and reduced funding for development programs. RPV technology has not been vigorously pursued by the military. Most experts ranked user apathy as the most important reason for the lack of RPV use (35:8). There are only two RPV programs currently under full-scale or engineering development --the Air Force's Low Cost Expendable Harassment Vehicle, called Locust, and the Army's Tactical RPV program (35:8-12).

Airframe development. The XBQM-106 prototype airframe was established in 1975 as a result of the evolution of the expendable target strike RPV requirement (Locust). This vehicle has flown at gross weights ranging from 115 to 230 lbs with payloads ranging from 25 to 135 lbs. The heaviest wing loading flown was almost 13 lbs/ft$^2$. It has been propelled by two-cycle gasoline propeller engines ranging from 12 to 25 hp. At present the airframes are constructed of hand lain fiber glass and foam materials. However, research is underway investigating construction using other materials including polyurethane foam (18:16-17).

The launch of Mini-RPVs using small solid-fueled rockets was successfully tested at the Air Force Rocket Propulsion Laboratory. The rocket booster units, similar to ones available in hobby stores for model rockets, are simple to operate and cost less than a pneumatic system (33:2). The vehicle recovery was proven to be relatively easy. Moderately skilled flyers were able to bring the RPV into a small area and land with great accuracy. As the aircraft makes its landing approach a ram air canopy (parafoil) is deployed which contributes to very stable flight control at slow speeds. With the parafoil deployed the XBQM-106 lands gently on a replaceable skid attached to its belly (18:34-36).

Instrumentation development. Two avionic packages were assessed by project "Teleplane", one called an Electrostatic Autopilot and the other a Fluidic Autopilot. The first has been determined unsuitable for an operational system because obstructions and weather conditions distort the earth's E-field. However, the Fluidic Autopilot, developed

by NASA Langley, did test out to be feasible for an operational system. Basically, the system uses a simple fluidic rate sensor which can be coupled with heading and altitude devices to provide cruise flight stabilization (19:7-8).

The U.S. Army's Tactical RPV system has two subsystems that may be applicable to this study. One subsystem is the Forward Looking Infrared (FLIR) television system that is being developed by the Army Night Vision Laboratory in Fort Belvoir, Virginia and is currently in the advanced development stage. The other subsystem is its flight control electronic system which is digital with memory capabilities. It utilizes an attitude reference system, based on a modified strapdown inertial unit, that enables it to operate for periods of time without ground station commands. This system is highly automated and therefore, does not require extensive operator training (11:58-60).

Advantages of RPVs. A survey of the experts identified several missions; such as harassment, decoy, surveillance/reconnaissance, and electronic warfare support; for which an RPV is held to be better suited than manned aircraft. The most advantageous military use of RPVs would be in a hostile environment or on a mission which would be boring or fatiguing for the pilot, such as reconnaissance or surveillance missions. RPVs are considered to be cheaper than manned aircraft; the cost and training of a ground controller is substantially less than for a pilot; they save fuel; and their small size enhances survivability and reduces replacement costs. Disregarding the humanitarian considerations, the capital investment lost when a pilot is killed or incapacitated is sufficient to make the use of RPVs a logical alternative whenever possible (35:1-3,17,18).

Disadvantages of RPVs. The most widely perceived disadvantages to military unmanned systems are their performance under emergency or unforeseen conditions, recovery difficulties, possible home base vulnerability to attack, and to a lesser degree, the lack of remote sensing and data link technologies. However, the experts do not believe that the state of the art is a major hinderance to the use of RPVs as an alternative for manned systems. The present limitations were seen as surmountable problems which could be overcome if a real interest in the vehicles were to develop (35:6,18,19).

## Methodology

This study will address four areas in order to answer the AFWL's question: "Can an RPV system effectively assess intrusion alarms at remote missile sites at a cost less than that of manned helicopter assessment?" First, the requirements that an RPV system would have to meet so that it can effectively assess remote missile site intrusion alarms will be identified. Second, an RPV system will be configured based on capabilities, costs, and the likelihood of meeting the imposed requirements. Third, the capabilities and the associated cost of the UH-1N helicopter system will be identified. Fourth, the capabilities and costs of the two systems will be compared to each other to determine if the selected RPV system is a viable means of intrusion alarm assessment.

RPV requirements. The RPV requirements will be established by the AFWL/Nuclear Weapons Security Branch and the experts in other RPV related DOD organizations. Requirements will be specified for the

airframe, video system, guidance and control package, and costs. These requirements will be used as constraints for choosing the RPV subsystems.

RPV configuration. The RPV configuration will be the result of integrating existing subsystems with selection criteria based on flight time limitations, range of operation, payload capabilities, maintenance requirements, noise levels, deployment and recovery capabilities, weather capabilities, guidance and control capabilities, manning requirements, attrition rates, costs, and availability. Selecting the subsystems will be a four step process. First, a review of the published literature will be made of existing RPV systems. Second, a detailed study will be made of any RPV subsystem that appears to have an application toward remote intrustion alarm assessment. These studies should reveal through test results the capabilities of each RPV subsystem. Third, based on the test results and expert opinions, a determination will be made of which subsystems would be better suited for this application. This includes the weight and dimensions of any subsystem under consideration being compatible with the selected airframe. Fourth, the criteria to choose between two or more satisfactory subsystems will be the lowest cost and whether or not it is a part of an existing DOD program.

Helicopter capabilities and costs. The capabilities and costs for the UH-1N helicopter system will be identified. Since it is an operational AF system, data should be readily available. Data of interest for its capabilities will include range, velocities, and weather restrictions for take off, flight, and landing. Cost data

will entail initial procurement, maintenance, operational, and crew training costs.

RPV suitability. The final analysis will determine if the selected RPV system is a viable alternative to a manned helicopter system. The RPV system capabilities will be analyzed to see if the imposed requirements can be met. The capabilities of the two systems will be compared directly to each other. Any advantages and disadvantages of the two systems that are revealed by the study will be presented. If the RPV system is then deemed capable of effective remote intrusion alarm assessment, its viability will be based on whether or not it costs less than the UH-1N helicopter system.

# CHAPTER II

# SURVEILLANCE SYSTEM REQUIREMENTS

The RPV system requirements were derived through interviews with experts at the AFWL Nuclear Weapons Security Branch, AF Aeronautical Systems Division (ASD) RPV Division, AF Flight Dynamics Laboratory, and the Army RPV Program.

## Airframe

The airframe selected should be relatively small and inexpensive. It will have to carry a payload that includes a video system, control and guidance components, and fuel. The aerodynamic design should be such that the plane is fuel efficient, stall averse, able to maintain flight through inclement weather, and very stable at slow loiter and recovery speeds. Personnel with minimal RPV flight training will be performing the launch, flight, and recovery operations. Therefore, the airframe must lend itself to simplistic launch, flight control and recovery methods. This RPV should be capable of surveying a target missile silo 160 miles away and returning to homebase. This target distance was derived from the existing Minuteman silo maximum distance from the Strategic Missile Support Base (SMSB) (6:20). A maximum intrusion alarm response time of 60 minutes was imposed for this study.

## Video System

The video system will have to deliver a real time picture from distances ranging from 0-160 miles. The video display needs to have

enough resolution that on a clear day or night at an altitude of 1,000 feet, it will be able to distinguish a human being four feet tall weighing 75 lbs or larger in statue. It must be able to distinguish during night or day a human of the same statue in inclement weather from an altitude of 500 feet. The system should also have sufficient resolution that at an altitude of 3,000 feet large check points en route can be identified for navigational purposes. The camera must be capable of zooming and rotating on gimbals to give variable angles of view. It is desirable that the video system have the capability to fix on a large object such as a missile site while the RPV is in a loiter mode. Of course, the video system must be light enough that the aggregate weight of it, the fuel, and the control and guidance package is less than the RPV's payload limit. Its dimensions will have to be small relative to the airframe to minimize its effect on the airframe's aerodynamic properties.

## Guidance and Control/Data Link/Ground Station

The system should be capable of multiple vehicle control by personnel with minimal flight control training. It should be programmable for automatic flight control with the exception of launch and recovery operations which could be accomplished by manual control. This will require the ability to transfer vehicle control from local to remote transmitters. It should have sufficient range to allow surveillance of the target missile silo distance and be able to provide real time video, aircraft positions, and flight characteristics data displays to the ground controllers. It is

imperative that the onboard control package be equipped with a loiter mode and contain a means to automatically reacquire the command data link whenever the RPV loses contact with the ground control station. The system should be able to function over all types of terrain and in all types of weather that might be experienced in the continental United States.

## Costs

The total system costs will be one of the main factors that will determine system feasibility. The UH-1N helicopter system equipped for all weather surveillance was proposed for cost comparison purposes. The RPV system production, installation, operations, and maintenance costs should be less than those of a manned UH-1N helicopter system. All costs used in this document will be in 1982 dollars unless otherwise stated.

# CHAPTER III

# ANALYSIS OF RPV AND HELICOPTER SYSTEM CAPABILITIES AND COSTS

## RPV System

The AF ASD RPV Division was visited to determine the general type of RPV system required. The larger fan jet propelled RPV system would be capable of accomplishing our objectives, however the costs and maintenance requirements would be excessive. The gasoline engine propelled Mini-RPV system would also be capable of accomplishing our objectives and would keep the costs and maintenance requirements to a minimum (25). The latter system was selected for evaluation in this thesis.

The Air Force and Army RPV programs were the only Mini-RPV programs found that utilized an active guidance and control/data link and a recoverable air vehicle. These programs were surveyed to identify an RPV system capable of satisfying the objectives of this thesis.

### Airframe

The Army's Mini-RPV, the Tactical RPV, is the follow-on project of the Aquila RPV program. It has the same airframe as the Aquila, which is a flying delta wing. The Air Force's Mini-RPV is called the XBQM-106. It has a conventional monoplane pusher configuration, which is a more stable aerodynamic design at the slower loiter speeds than a flying wing, and its estimated production cost is considerably less

than the $40,000 (1979 dollars) cost of the Army's airframe. Thus, the XBQM-106 airframe was selected for intrusion alarm assessment.

Airframe description. The current version of the XBQM-106 is an excellent flying vehicle in stabilized and non-stabilized control modes. Control coupling between all axes is minimal. Dampening in all axes and directional stability is very good; spiral stability is intentionally neutral (5:2).

Thus far, the normal means of launching has been from a pneumatic coil launcher. However, a much less costly method was tested at the AF Rocket Propulsion Laboratory. This method uses a rail launch, assisted by an expendable mini-rocket. Rockets such as these are very inexpensive and are similar to ones available at local hobby shops. Landing occurs on a replaceable skid affixed to the underbody (32:2).

The assembly is modular, which allows for replacement of the wing, tail, engine, nose section, and the payload packages. The fuselage and vertical tail are constructed of fiber glass. The wing and horizontal tail panels are constructed of polystyrene foam covered with epoxy-coated plywood veneer (4:4).

The gross weight is usually in the vicinity of 200 lbs, depending on the weight of the payload that is located in the nose. Many missions have flown well at gross weights in excess of 225 lbs, 230 lbs being the heaviest. The nose is tailored to fit the customer requirements within acceptable aerodynamic and center of gravity limits (5:2-3).

At 200 lbs, the vehicle load limit will approximate ± 5.5 g's in pitch, 2.0 g's in yaw, and 10 g's longitudinal for launch. The plane

is powered by an 18 hp engine driving a 26" x 13" pitch propeller. Consequently, the frame is not critically stressed during flight (5:4).

The XBQM-106 is pictured in Figure 3-1. Figure 3-2 is a drawing of the plane's general arrangement and the bulkhead drawing is depicted in Figure 3-3. A list of nominal component weight is included in Table 3-1.

The aircraft as delivered includes the following installed items:

1. Wing, tail, fuselage, payload shroud and engine cowl structures.
2. Wing and tail aluminum spars, aileron and stabilator hinging and actuation mechanism.
3. Replaceable forward landing skid and aft ventral fin.
4. Replaceable side force surfaces (2), and installation spars and fittings.[1]
5. Fuel tank, plumbing and filter (2.8 gal capacity).[2]
6. Engine - DH Enterprises 220 - 18 hp.
7. Propeller - 26" diameter x 13" pitch.
8. Engine/alternator mount - special shock mounting using three "Aeroflex" mounts.
9. Voltage Regulator - KBG model 10227.

---

[1] Side force surfaces give the airframe a tighter response to aerobatic maneuvers at the expense of a slight increase in drag, thus fuel consumption is increased and range decreased. Since quick maneuvers are not required in this application, side forces would not be used.

[2] The fuel consumption for the DH 220 engine is approximately 2.4 gal/hr at a cruise of 80-90 MPH. Therefore, the fuel tank capacity must be increased to meet the range requirements. The fuel capacity is limited by volume of the airframe, but it can be increased to 12 gallons. Eight gallons can be stored in the fuselage and nose section below the wing and four gallons can be stored in the wings (37).

10. L-band antenna and coax-KBG model 10102.

11. Servos [aileron (2), throttle (1), elevator (1), rudder (1)] - KBG model 10344.

12. Battery pack - lead acid, 26 volt, 2.5 amp hr.

13. Wiring harness - wing j servos, control position pots and magnetometer j fuselage, servos, battery, alternator.

14. Pitot tube and plumbing - Centrol model no. C-5255.

15. Engine CD ignition unit - KBG model 10308.

16. Control surface position pots and mounting - KBG model 10145.

17. Magnometer (wing tip) mount bracket - KBG 10195.

18. Charge plus - DAMA-155 crimp type.

The AF Flight Dynamics Lab has flight tested the XBQM-106 with a small parafoil attached. The parafoil is remotely deployed upon approach for landing. When the parafoil is deployed, the vehicle flies very slow and becomes very easy to control using a hand-held radio control box. Personnel with no prior remote control pilot experience were able to maneuver the airframe with great accuracy. The weight of the parafoil system is approximately 15 lbs (18:34-36).

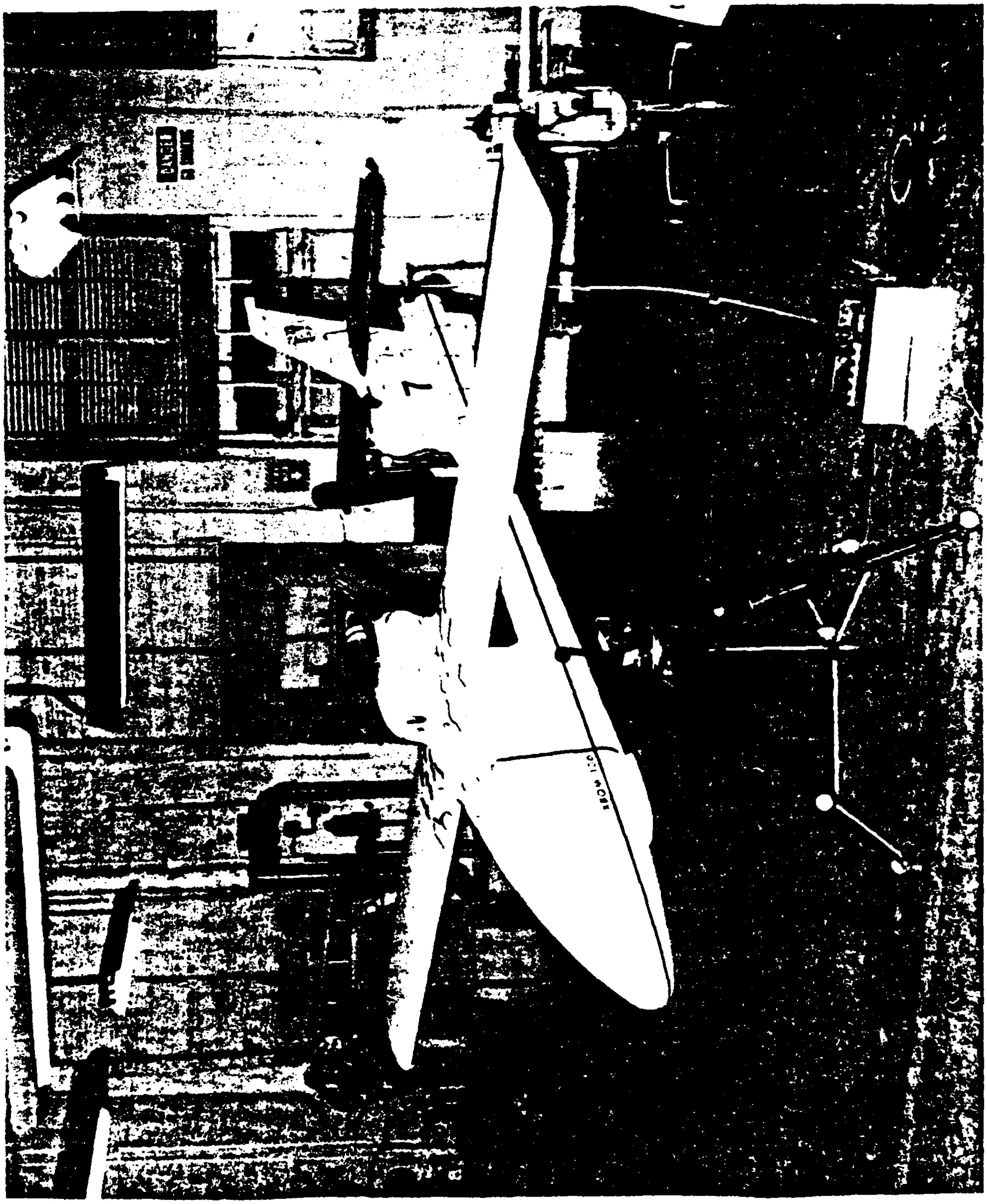

Figure 3-1

XBQM-106 (4:52)

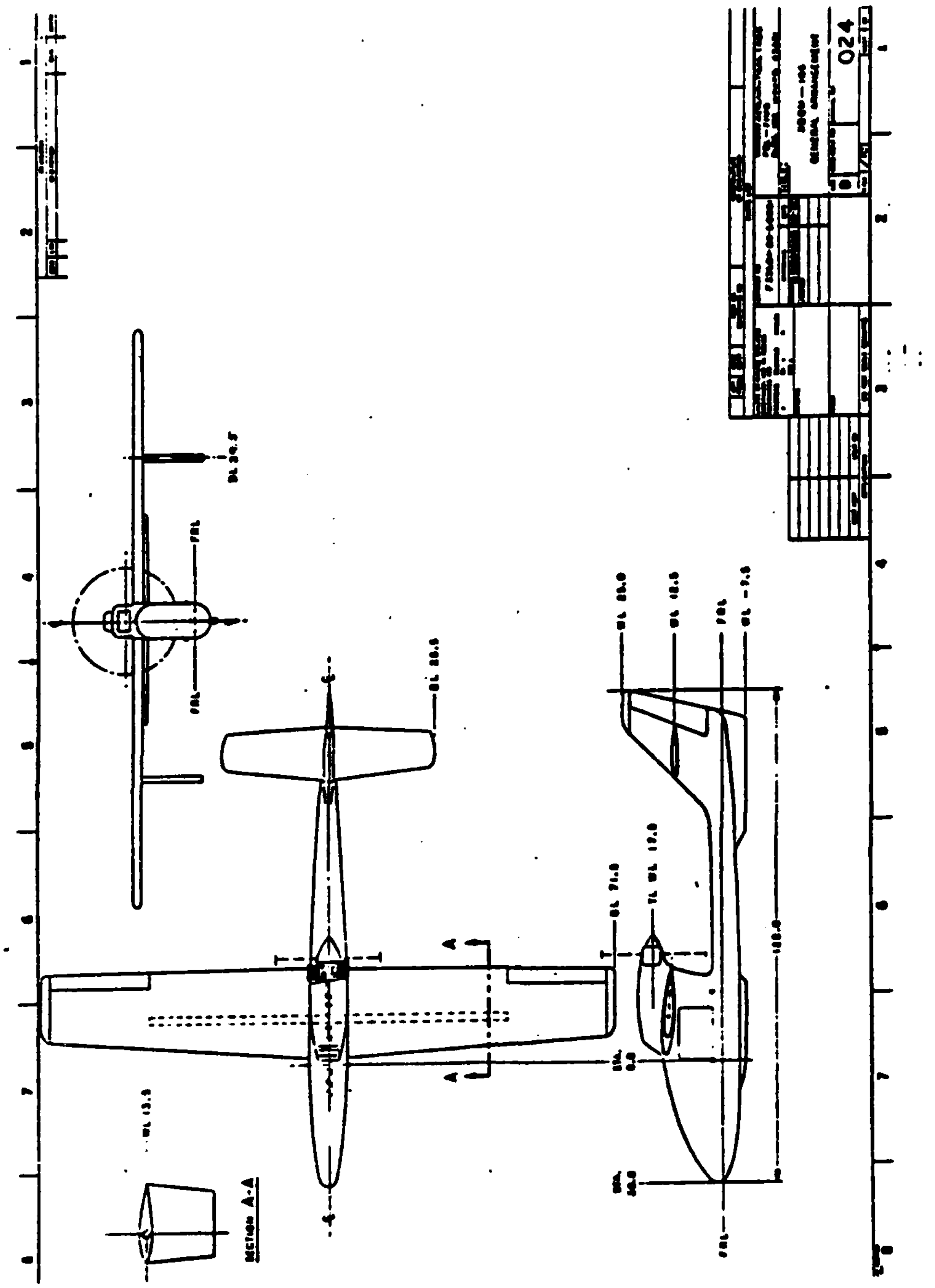

Figure 3-2

XBQM-106
General Arrangement (5:17)

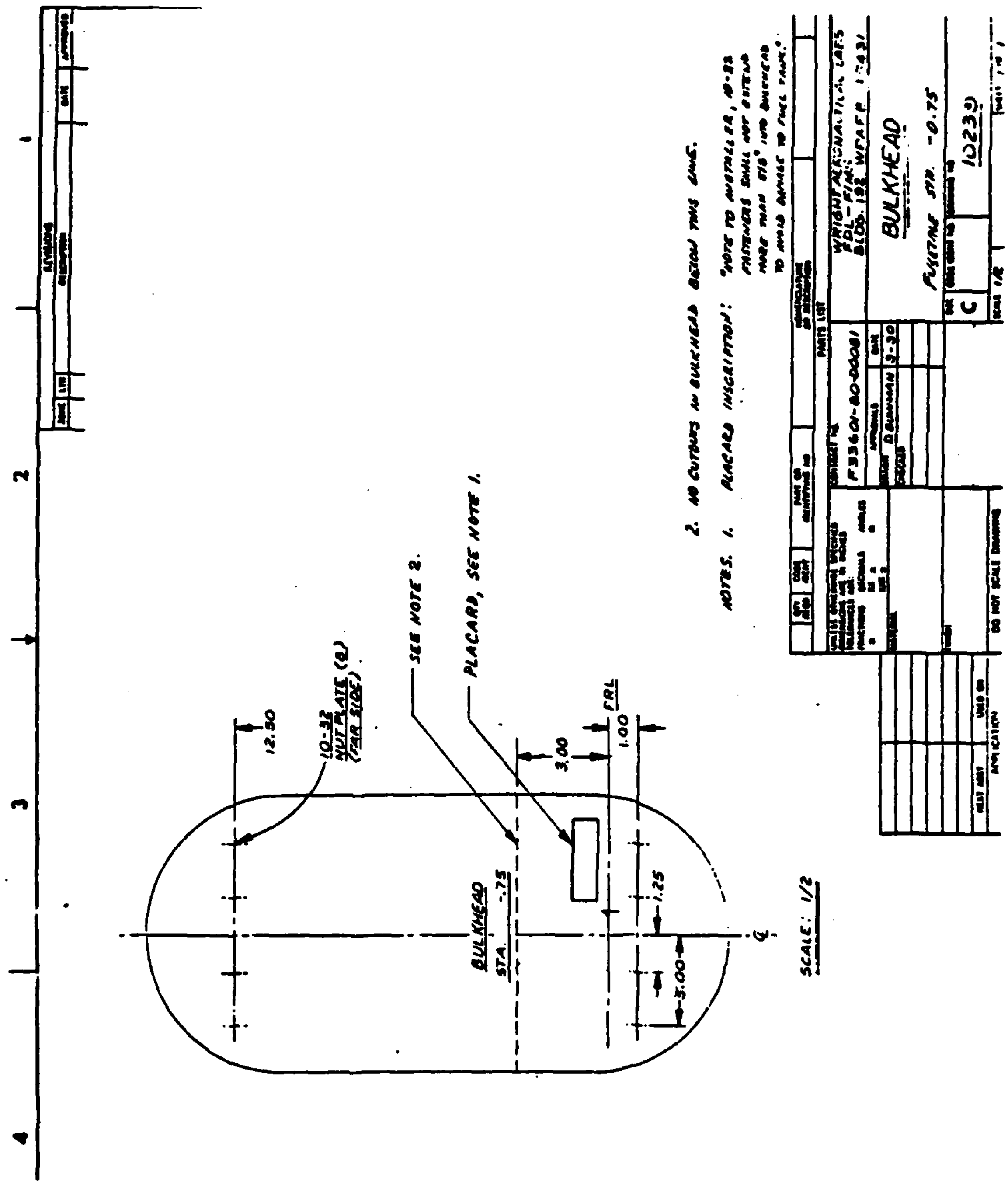


Figure 3-3

XBQM-106 Bulkhead (5:18)

TABLE 3-1

XBQM-106 WEIGHTS

| Item | Weight (lbs) |
|---|---|
| Fuselage* | 25.89 |
| Left Wing and Harness | 8.14 |
| Right Wing and Harness | 8.33 |
| Wing Spar | 7.66 |
| Left Stabilator | 1.28 |
| Right Stabilator | 1.28 |
| Stabilator Spar | .28 |
| Mass Balance - Left | .22 |
| Mass Balance - Right | .22 |
| Engine Fairing | .99 |
| Nose Shroud (Have Pawn) | 3.09 |
| Stabilator Servo and Linkage | .55 |
| Left Aileron Servo and Linkage | .55 |
| Right Aileron Servo and Linkage | .55 |
| Throttle Servo and Linkage | .48 |
| Ignition (including cables) | 2.41 |
| Rudder Servo and Linkage | .55 |
| Antenna | .12 |
| Engine Mount | 3.28 |
| Engine | 13.80 |
| Propeller | 1.29 |
| Alternator with Coupling | 6.22 |
| Magnetometer and Mount | .30 |
| +26V Lead Acid Battery Pack | 5.81 |
| Pitot Tube | .15 |
| Subrudder | .43 |
| Regulator | .28 |
| | 94.15 Empty Weight |

*Fuselage includes ventral skid, tail skid, gas tank, wing anti-rotation pin, and tail harness.

SOURCE: RPV Model Shop (5:19).

Vehicle performance. The expected performance data below is for an airframe with a gross weight of 230 lbs and an 18 hp, 2-cycle engine using a 26" diameter x 13" pitch propeller. The wind velocity is 0 MPH (5:38).

| | |
|---|---|
| Take-off unassisted | 750 ft |
| Pneumatic Launch | 10 g max |
| Velocity | |
| Take off | 50 MPH |
| Land (no parafoil) | 54 MPH |
| Cruise | 80 MPH |
| Max level | 102 MPH |
| Max dive | 204 MPH |
| Climb | 900 ft/min |
| Range | 400 miles max |

The airframe MTBF has not been calculated, but there have been no airframe or engine failures related to flight. During one test the airframe was damaged (cracked fuselage) upon landing when it hit a swell in the runway. The airframe was repaired on the spot and testing was continued. The projected maintenance schedule for the DH-220 engine is every 200 hrs of flying time (8).

Flight Environment. The flight environment is as follows:

| | |
|---|---|
| Max. Altitude | 10,000 ft |
| Ambient Temperature | +20°F to +120°F[1] |
| Relative Humidity | 10 to 95% noncondensing |
| Launch Acceleration | 10 g's peak, half-sine pulse, with 0.44 second time base in the longitudinal axis |

[1]Planes flown in environments less than 20°F would have to have engine intake modifications that would use engine heat to preheat the air. Otherwise, icing would occur in the carburetor that would stall the engine (14).

| | |
|---|---|
| Landing Shock | 15 g's peak, half-sine pulse, with 0.050 second time base in the vertical axis |
| Flight Vibration | 2 g's RMS discrete vibration from 20 Hz to 2 KHz |
| Wind Restrictions | |
| Take Off | 30 knots |
| Landing | 20 knots |
| Flight Maneuvers | |
| Pitch | 5.5 g's |
| Yaw | 2 g's |

Airframe cost. The XBQM-106 contractor is Centro, Inc. located in Dayton, Ohio. The lead engineer of Centro was contacted for an unofficial price quote. The price quoted includes the airframe and the 18 components listed above. The airframe would cost approximately $15,000 per copy if the contract is to be for 50 planes. The cost of the parafoil adds $750 to each airframe (37).

## Video System

The literature review revealed that the only satisfactory real-time video system would be an infrared (IR) video system. There are some excellent miniature TV cameras that give clear images with very little light--star light, for example. However, clouds, smoke, fog, and smog can totally mask ground images. Thus, the low light TV's are unacceptable. On the other hand, such obstructions will not mask IR imagery.

The only IR video system currently produced that is small enough for the XBQM-106 is Honeywell's high performance, lightweight, low power Forward Looking Infrared (FLIR) sensor model no. YK48AIF. This

is the system designed for the night sensor payload of the Army's Tactical RPV and is called the MINI-FLIR. It has a wide and narrow field of view and is compatible with a line of sight and tracking system. A line of sight and tracking system using a laser designator is incorporated in the Army's Tactical RPV. A laser is not needed for this application, so the conventional cross hair tracking electronics would be applied.

While at the Army RPV SPO, the authors viewed a video tape of this IR video system. The video tape was produced by the Army's Night Vision Laboratory during a test flight of the MINI-FLIR mounted on a helicopter. Its ability to distinguish tanks, jeeps, armored personnel carriers, and even vehicle tracks from a relatively high altitude (classified) was surprising. It was the opinion of the experts at the Army's RPV SPO and a Honeywell representative (22) that the MINI-FLIR easily has the capability to meet the detection criteria listed in Chapter 2. They noted that detection would possibly not occur during very severe weather such as a blizzard. However, the probability of travel over a distance by any mode under such conditions by offender or defender would be small.

MINI-FLIR principles. The MINI-FLIR is a highly efficient serial scanned, thermal imaging sensor. The infrared energy emanating from objects in its field of view is gathered by an optical system specially designed for peak transmission in the 7.5 to 11.5 um wavelength. This energy is scanned in the horizontal direction with a continuously rotating 8-faceted mirror, and by a flat mirror in the vertical direction. The output signal from the detector is amplified

and processed to provide gain and level control. The output of the detector signal is standard EIA-RS-330 television compatible. Therefore, any 525-line TV monitor or video recorder conforming to the United States EIA-RS-330 standard can be used for viewing the presentation. Figure 3-4 shows the basic FLIR principles (36:5).

MINI-FLIR physical description. The MINI-FLIR consists of four assemblies. The four assemblies are the sensor, pre-amplifier, 1/4 watt split sterling closed cycle cooler, and the auxiliary electronics. A control panel, external to the unit, contains switches and a control potentiometer to provide operator control during operation. The total weight related to the MINI-FLIR that would be carried by the airframe is 50 lbs. This weight is derived from the fully operational MINI-FLIR used for the Army's Tactical RPV. The Army's unit weighs 61 lbs but the 11 lb laser system which is not needed in this application has been subtracted. The 50 lbs includes the mount, gimbals, elevation assembly, azimuth assembly and the electronics unit (22). The FLIR to be mounted in the XBQM-106 would occupy less volume than 9" x 9" x 10". The MINI-FLIR being used in the Army's Tactical RPV program is pictured in Figure 3-5.

MINI-FLIR Performance. The narrow field of view is 3.2° horizontal and 2.1° vertical with 12.16X magnification. The wide field of view is 11.5° horizontal and 7.5° vertical with 3.18X magnification. The percent distortion is $\leq 1\%$ center, $\leq 5\%$ edge azimuth, $\leq 5\%$ edge elevation. The scan efficiency is 85% for elevation, 42% for azimuth.

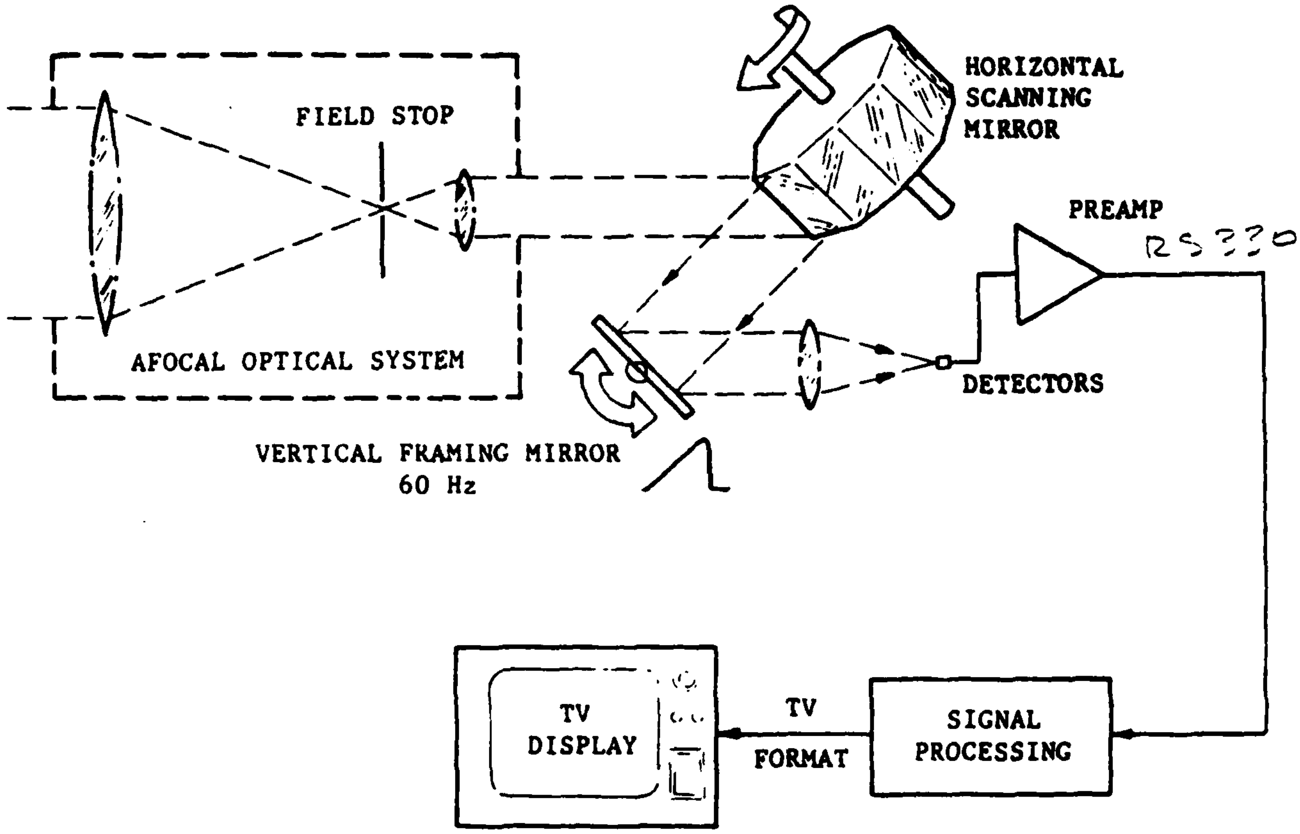


Figure 3-4

Basic FLIR Principles (30:5)

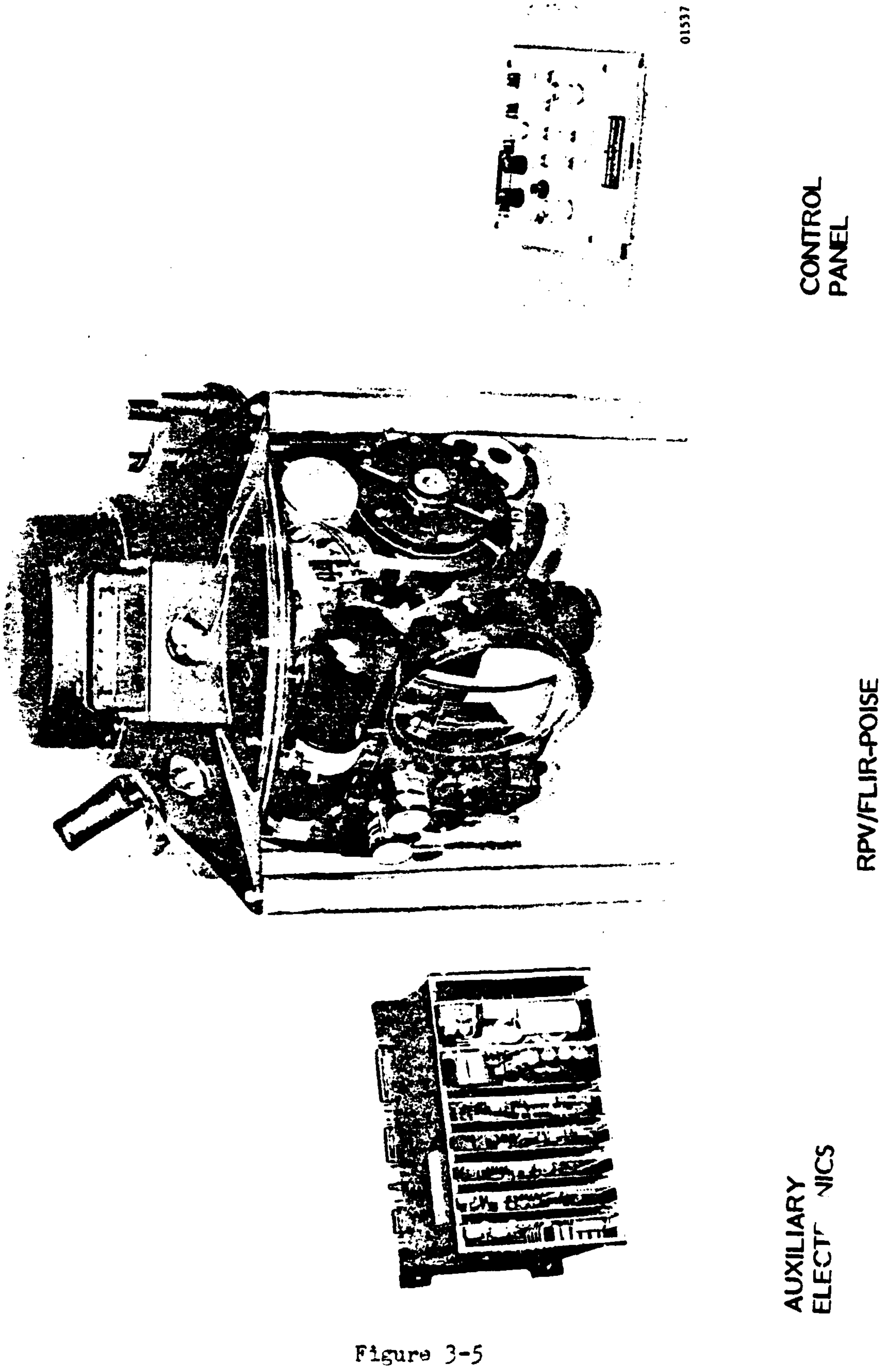


Figure 3-5

MINI-FLIR (30:15)

The MINI-FLIR is capable of withstanding the vibration, shock, and temperatures to which it would be exposed in launch, flight, and recovery operations of the XBQM-106. The system is designed to withstand vibrations of 2.5 g's from 5 Hz to 100 Hz and 3.5 g's from 100 Hz to 200 Hz. The system acceptance test includes shocks in all three axes for a total of 18 shocks, each of which is 11 ms long, with a peak of 20 g's.

The system is operable between -26°F and 120°F and it can be stored between -35°F and 160°F. It can be exposed to 100% relative humidity from -26°F to 84°F and to humidities corresponding to a dew point of 84°F to 120°F.

The MINI-FLIR is a very reliable component. The probability of its completing a three-hour mission without a failure in an aircraft environment over temperatures cf -25°F to 120°F is 99.7%. The predicted mean time between failures (MTBF) using MIL-STD-217B is 1100 hours (36:4-12).

MINI-FLIR cost. The experts in the Army RPV SPO and Honeywell stated that today's cost of the complete MINI-FLIR package for the Army's RPV program would be on the order of $200,000 per copy. Since the XBQM-106 would not need a laser, a Honeywell representative was contacted for an estimate of the cost without the laser. The representative unofficially quoted a cost of $140,000 per copy. This cost includes the cross hair tracking system (22).

## Guidance and Control/Data Link/Ground Station

The Air Force Mini-RPV program utilizes a manual control system in conjunction with a flight stabilization package. This system

requires constant control by an instrument-qualified ground controller, and would require a separate ground terminal and controller for every RPV in flight (8). This "hands on" requirement, along with the excessive ground controller training requirements, makes this system unacceptable for our purpose.

The Army's Tactical RPV program utilizes an automatic guidance and control system that is more acceptable for our purpose. This system consists of an Attitude Reference Assembly (ARA), a Flight Control Electronics Package (FCEP), an Air Data Terminal (ADT), a Remote Ground Terminal (RGT), and a Ground Control Station (GCS) as shown in Figures 3-6, 3-7, and 3-8 (23).

The ARA. The ARA is a modified strapdown inertial unit that includes the precision inertial sensors and associated electronics used to measure air vehicle pitch, roll, and heading; attitude and air vehicle translation velocities; and acceleration used in navigation. Its dimensions are 12.45" x 10.00" x 2.63"; its production cost is approximately $27,105 (1979 dollars) ($37,696 - 1982 dollars[1]) (9; 11:58; 23; 32:21).

The FCEP. The FCEP serves two functions. As the air vehicle autopilot, it performs the necessary signal processing of flight sensor instrumentation inputs from the ARA and the barametric attitude and airspeed transducers to provide commands to the actuators controlling the air vehicle's flight. It also acts as the interface for the data link, mission payload, and on-vehicle electrical equipment. This system, developed by Singer Co./Kearfott Div., has enough on-board computer memory to provide a "run-silent" capability

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[1]Conversion factors for inflation are shown on page 43.

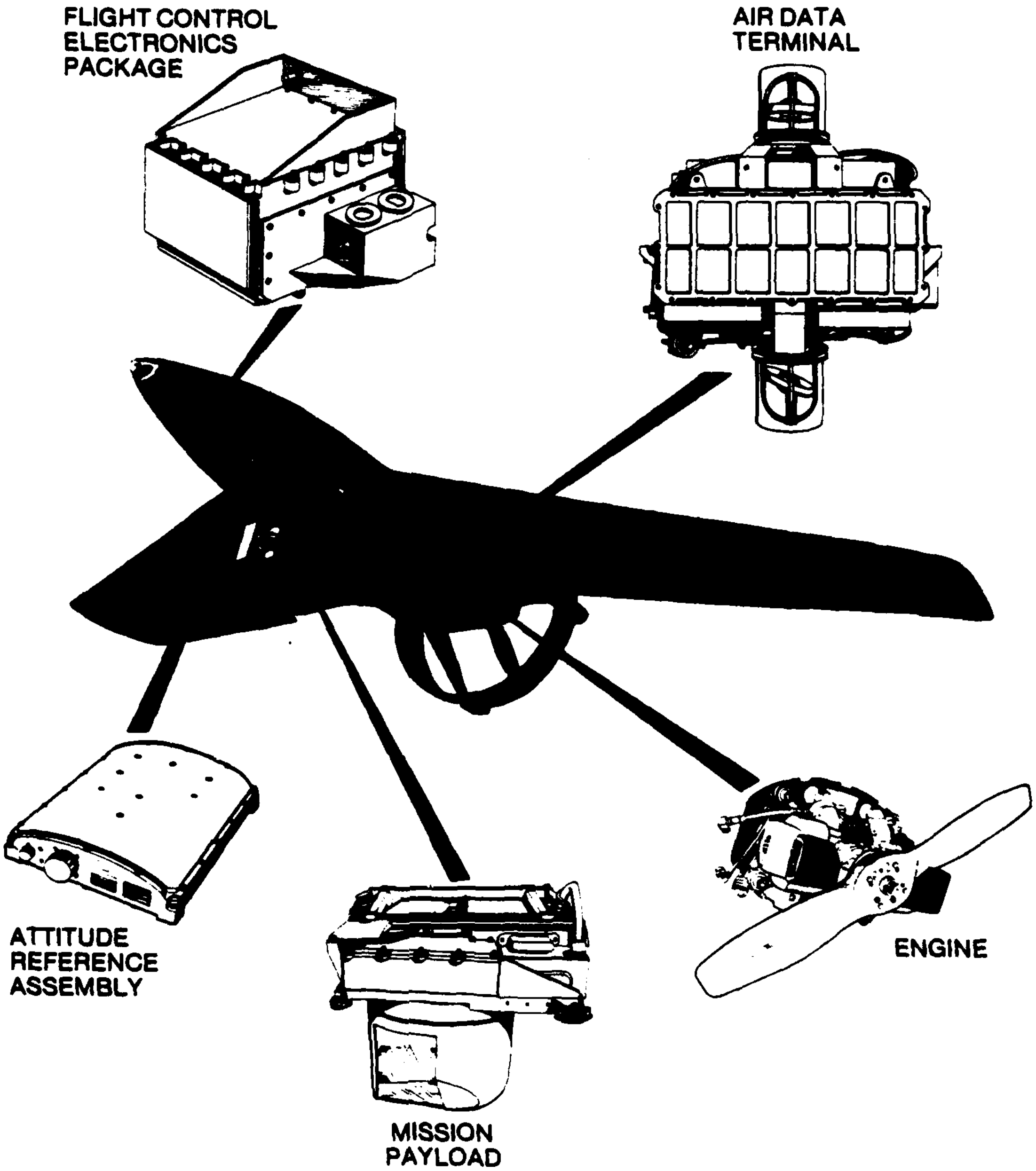


Figure 3-6

Air Vehicle Components (23)

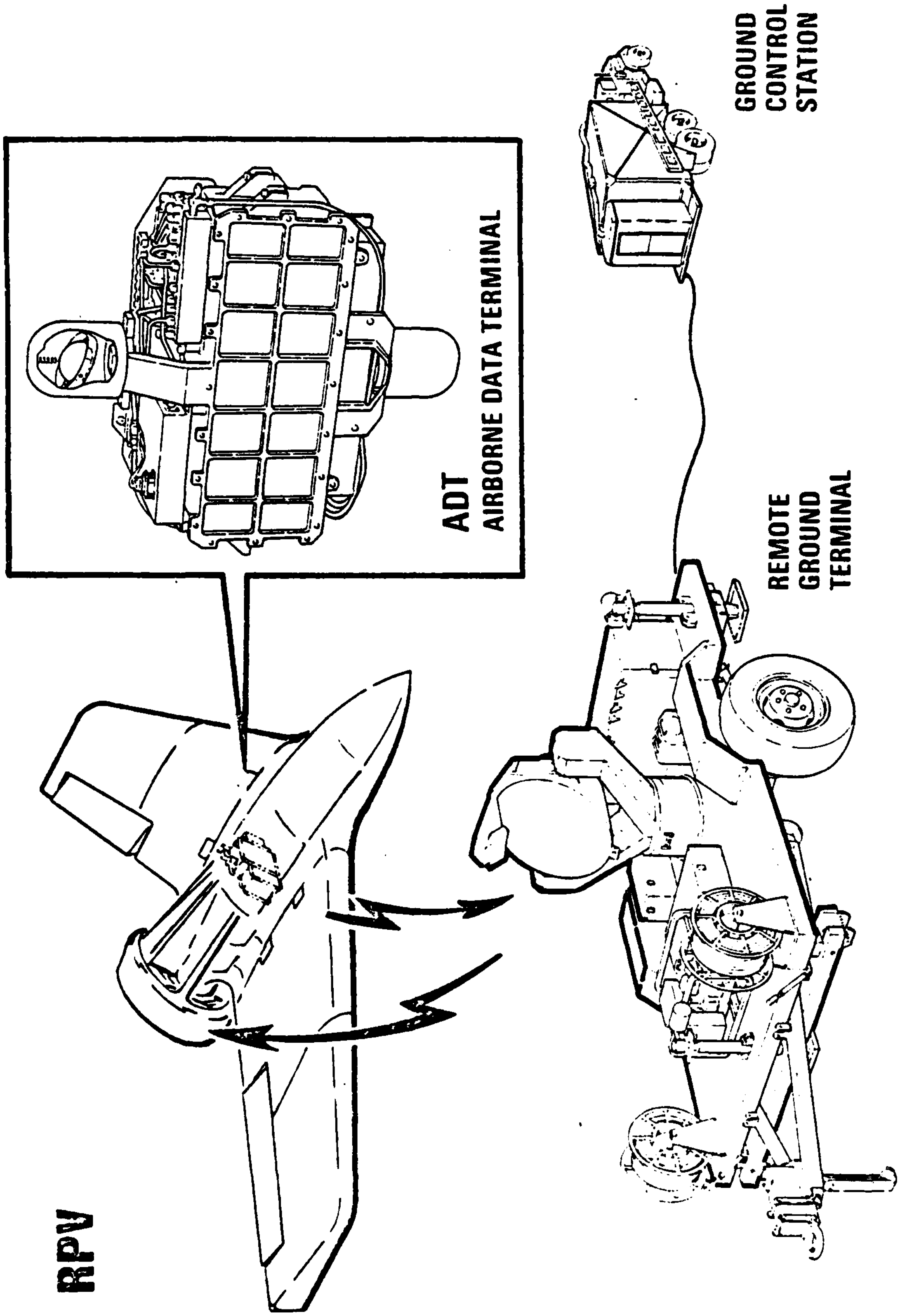


Figure 3-7

Remote Ground Terminal (23)

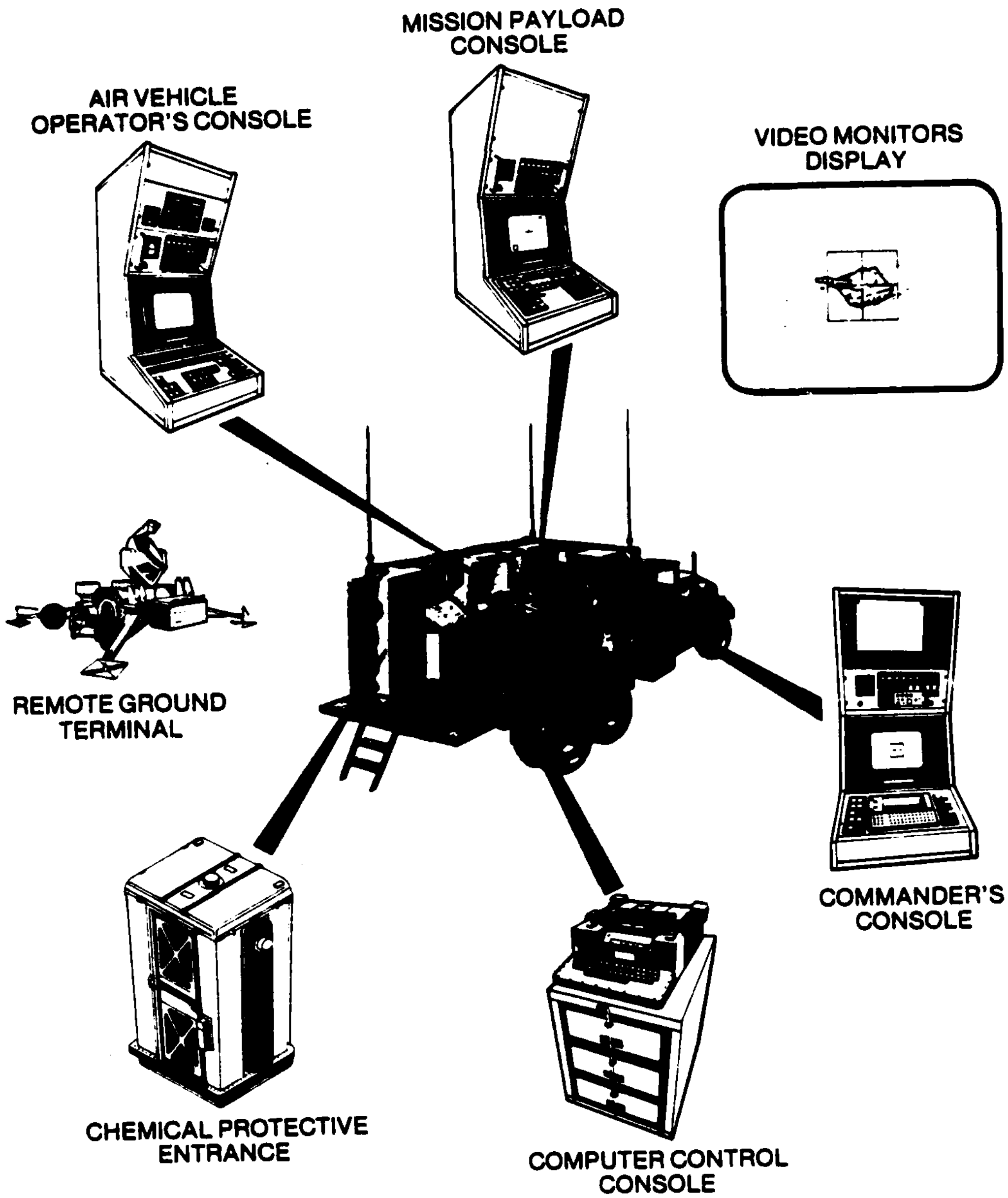


Figure 3-8

Ground Control Station (23)

that allows the air vehicle to operate for periods of time without commands from the ground station. The system's weight is approximately 16 lbs, its MTBF is 2513 hrs, its size is approximately 12.3" x 5.7" x 7.9", and its production cost is approximately $32,078 (1979 dollars) ($44,612 - 1982 dollars) (9; 11:59-60; 13; 23).

The ADT. The ADT, developed by Harris Corp., is a multiple data rate, highly integrated, lightweight, two-way, airborne, jam-resistant data link. It contains transmitters, receivers, and associated antennas shown in Figure 3-9 to uplink commands and downlink air vehicle status and video signals to the RGT. To protect against jamming, it incorporates spread-spectrum techniques to enhance the real signal relative to a jamming signal. The ADT transmits over either the top or the bottom two-axis steered directional antennas to provide maximum transmit capabilities at angles up to 60°. The receive array is mounted on the bottom of the shroud, where it has a full field of view during maneuvers. The data link is a line-of-sight system. Therefore, the air vehicle will operate at an altitude that varies with range and terrain in order to communicate with the ground station. In the event contact is lost, the FCEP is programmed to spiral the vehicle upward until radio contact is re-established. The ADT's dimensions are 13.8" x 12" x 5.45"; its MTBF is 1196 hrs; its weight is approximately 22 lbs; and its production cost is estimated at $114,572 (1981 dollars) ($125,341 - 1982 dollars) (9; 11:60; 23).

The RGT. The RGT includes a precision tracking, antenna, transmitter, receiver, and associated equipment that tracks, commands, and receives data from the air vehicle. It also provides the GCS

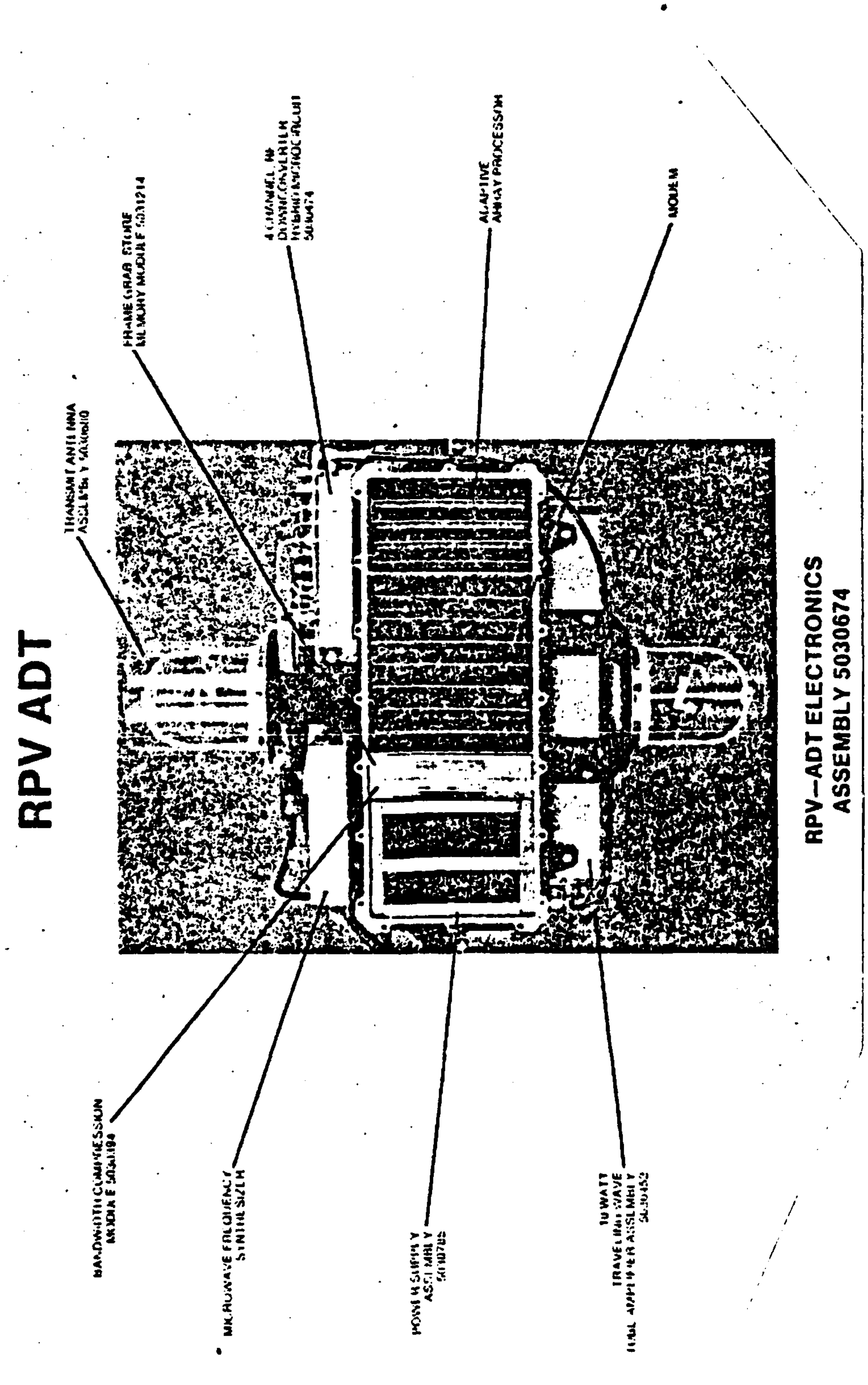


Figure 3-9

ADT Electronics Assembly (23)

computer with the range and bearing to the air vehicle. This combined with the surveyed location and azimuth references of the RGT from the GCS are utilized to accurately calculate the air vehicle location. The Army's prime purpose for locating the RGT apart from the GCS is to prevent hostile forces from locating the RPV ground base through electronic direction finding. For our purpose, the remote ground antenna will be utilized to increase the air vehicle's range and lower its minimal operating ceiling by locating the RGTs on high ground and using multiple RGTs and handing off the air vehicles from one RGT to a downrange RGT before radio contact is lost. The RGT's range is classified; its MTBF is 891 hrs; and its estimated production cost is \$270,528 (1978 dollars) (\$409,722 - 1982 dollars). This cost estimate includes the utilization of a laser fiber optics (LFO) data link to connect the RGT and the GCS for protection against Electro Magnetic Pulse (EMP) and other battlefield conditions that would damage the equipment (9; 11:60; 12; 23; 31:8). This type of data link would not be required for our system, based on the premise that a state of total nuclear war would exist for our system to be exposed to EMP. In this case, the United States would be launching its ICBMs and would not be concerned with intrusion alarms. The estimated production cost of the LFO system is \$10,000 (17). The cost of a buried, hard wire data link is approximately \$7,052 per mile (20; 26).

The GCS is shown in Figures 3-8 and 3-10. It is the operational control center of the RPV system. It provides facilities for flight planning, communications with and control of the air vehicle and its payload, automated checkout of the air vehicle prior to launch, and

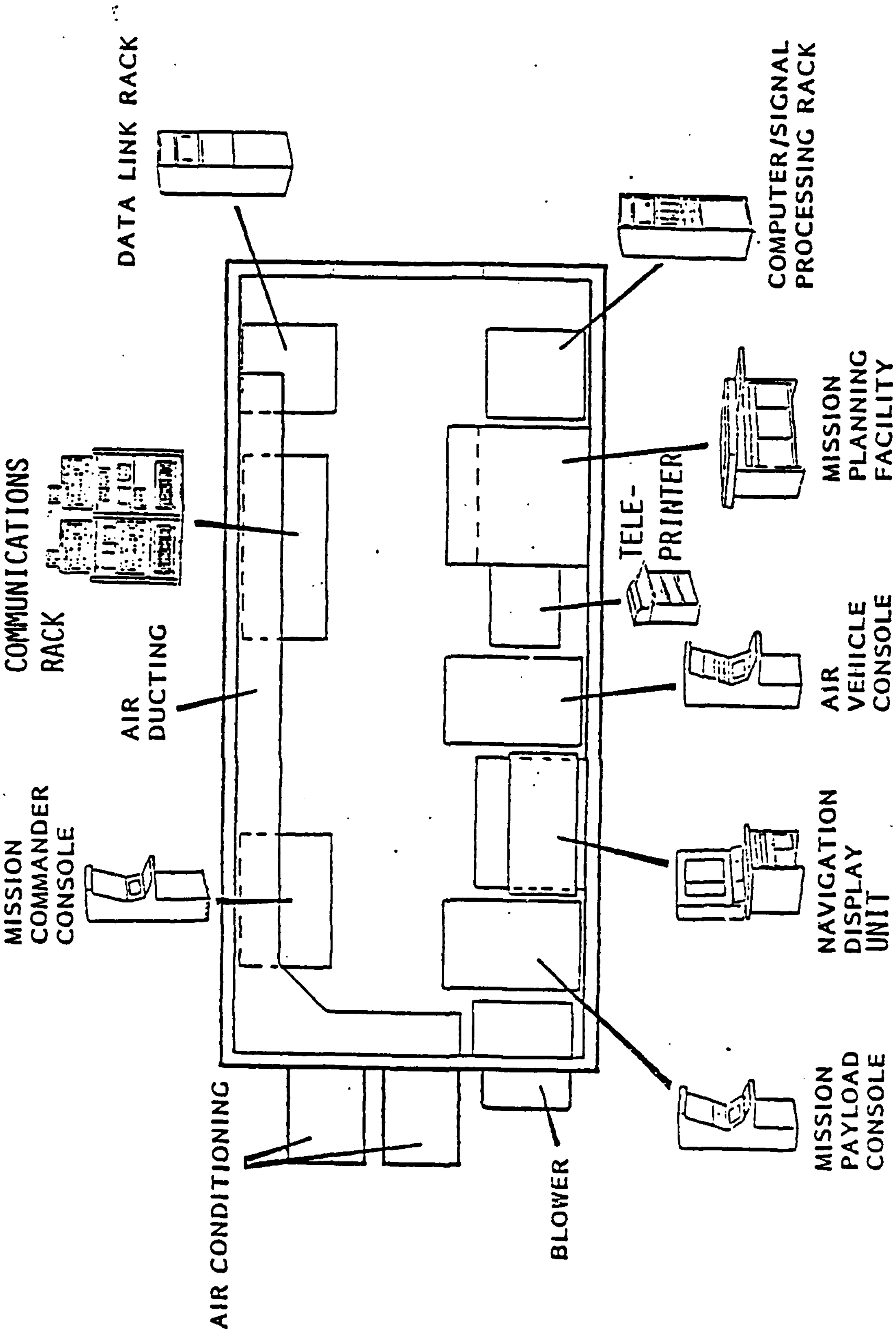


Figure 3-10

GCS Interior Layout (23)

operator training in a simulated operational environment. The following major consoles and equipment are housed in an environmentally controlled mobile shelter (11:59-63; 23; 31:5):

1. Air Vehicle Console
2. Navigation Display Unit
3. Teleprinter
4. Mission Payload Console
5. Mission Command Console
6. Communications Rack
7. Data Link Rack
8. Computer/Signal Processing Rack
9. Mission Planning Facility

The Air Vehicle Operation Control/Display Station incorporates all controls and displays required for operation of the air vehicle. This station includes a teletype for inserting the planned flight profiles; airspeed, altitude, and heading controls and displays for manual air vehicle control; an X-Y plotter for plotting aircraft position on a map of the local terrain; and an alphanumeric video display of the air vehicle's operational status. This system is highly automated because the air vehicle operator is not a pilot. The operator merely issues instructions to a computer specifying where, in map coordinates, the air vehicle is to go. All flight data can be pre-programmed into the system or can be manually inserted during flight. In the manual mode, the operator inputs the desired heading airspeed, altitude, and any turn requirements, and the air vehicle will accomplish this by a push of a button. In addition, the

operator's console provides for frequency selection control, pre-launch checkout, recovery mode, mission abort, RGT handover, and loiter mode selection (23; 31:17-20).

Launch and recovery of the proposed system will be accomplished on paved runways through the use of a manual hand-held control unit similar to ones used for remote controlled model aircraft. This method was selected to eliminate the costs associated with an automatic launch and recovery system which is not necessary for a fixed landing site (8).

The Mission Payload Station provides a similar interface between the operator and mission sensor payload as the air vehicle operator's station. The console provides a real-time video monitor capability of the payload sensor with a 360° azimuth sweep, 105° elevation position, three-position zoom, and an autotrack function (23; 31:20-22).

The Mission Commander's Station is the command post for supervision of the RPV missions and for coordination of all communications, both internal and external, to the system. The commander's console and communications rack include the required radio and hardware communication equipment, message data entry devices, mission payload and air vehicle status and position displays, and equipment to coordinate and control the execution of all RPV sorties (23; 31:22-23).

The Data Link Rack completes the data link between the GCS and the air vehicle. It provides controls and signals for steering the RGT antenna, frequency selection, code selection and synchronization, data link status reports, and transmitter selection. All signals

to and from the air vehicle and its payload are encoded or decoded by this unit (23; 31:8).

The Computer/Signal Processing Rack utilizes a Norden 1134M computer to provide computational storage, signal processing, control equipment, and software. The software performs the calculations for air vehicle control, target determination, management of the data flow, generation of command signals, and provides diagnostic testing of the hardware and software (23).

The Mission Planning Facility is utilized for the flight profile determination for the air vehicle's flight to and from the designated target. Target coordinates are derived from area maps. These along with the planned airspeed and altitudes to be flown are entered into the computer. The data is then played back, displayed as a complete flight profile on the X-Y plotter for verification, and printed out on the teleprinter. Where it is not practicable to maintain constant radio contact throughout the flight, programmed segments of dead-reckoning navigation can be included in the flight plan by entering waypoint coordinates at which such segments begin. Stored flight data can be used to run through a verification check in compressed time prior to launch. It is also possible to alter a flight plan during the course of a mission by manually changing the target coordinates and flight data. For our purpose, the mission planning will be greatly simplified since all of the mission targets will be fixed, known locations (23; 31:9, 12, 17).

The GCS was designed utilizing nuclear and chemical hardening and ballistic vulnerability reduction techniques. All consoles provide a

real-time video monitor with recording and instant replay capabilities. The GCS's multiple air vehicle control capability is limited by the RGT. Flight data can be obtained from only one RPV per RGT. Improvements to the system (RGT modification) to allow control of up to eight RPVs simultaneously are expected within the next five years. The GCS weighs approximately 10,000 lbs, its projected MTBF is 125 hrs, and its estimated production cost is $533,614 (1979 dollars) ($742,124 - 1982 dollars). Three personnel are required to man this system and their estimated training time is 12 weeks with a training cost of $8,000 per person (9; 12; 23). The RPV system total cost is presented in Chapter IV.

## Helicopter System

The UH-1N helicopter system was proposed by AFWL as a means of providing a cost comparison between the selected RPV system and a manned flight system. A similar helicopter system is currently available in limited numbers at the Minuteman bases (16).

### Flight Characteristics/Cost Data

The UH-1N system flight characteristics and cost data are (7; 10; 16; 21; 24):

1. Cruise speed
   a. Max - 130 knots
   b. Normal - 90 knots

2. Range - 289.8 miles at 90 knots[1]

3. Navigation

   a. No INS

   b. Does have night capability

4. Crew requirements - 2 pilots

5. Passenger capabilities - 13

6. Flight restrictions

   a. Wind - 45 knots

   b. Ceiling - 15,000 feet

   c. Temperature at flight altitude - 125°F to -65°F

   d. Visibility - 1/4 mile

7. Average down time - approximately 15 to 18%

8. Unit cost - $535,000

9. Flying hour based on fuel and maintenance - $384.80/hr

10. Pilot training cost (2 pilots) $235,080 - undergraduate Helicopter Pilot Training; $197,308 - UH-1N training

Manned helicopter systems equipped with night vision devices experienced numerous problems in the detection of missile site maintenance personnel on the ground during SAC Exercise Test Plan "Giant Sentry." The night vision devices require some form of light such as moonlight or starlight to be effective and will not function when the ground is obscured by smoke, fog, low cloud level, rain, snow, or camouflage (29:CH.4). For a more realistic comparison, we will utilize a UH-1N helicopter system equipped with a FLIR and a

[1] The range can be increased by utilizing fuel bladders in the passenger/cargo section of the aircraft. However, this will decrease the passenger capabilities.

real-time video monitor capability in the cockpit. FLIR's typically used with helicopters are more complex than the MINI-FLIR. They are better able to detect threats, but are much more expensive. For example, the HH60D is one of the latest AF helicopters being developed. Texas Instruments, Northrop, Huges and Honeywell are the vendors under consideration to produce its FLIR. The FLIR cost, regardless of who makes it, will be on the order of $350,000 (15). Because the MINI- FLIR performance is acceptable and it costs less, it will also be used in the UH-1N helicopter system.

# CHAPTER IV

# RESEARCH RESULTS

## Accomplishment of Requirements - RPV System

The following is an assessment of the selected RPV system's ability to accomplish the requirements listed in Chapter II.

Airframe. The selected RPV system is unable to fully meet the inclement weather and the maximum intrusion alarm response time requirements. The RPV system has wind restrictions of 30 knots for take off and 20 knots for recovery; flight temperature restrictions of below 20°F and above 120°F; severe rain and snow storm restrictions; and a minimum visibility requirement for recovery of 1/2 mile. The low flight temperature restrictions can be overcome by preheating the intake air to the carburetor. However, the other weather restrictions cannot be easily overcome. The wind restrictions are seen as a severe flight limitation and would greatly reduce the system's operational readiness. The severe rain and snow storm restrictions are not viewed as a significant limitation since most forms of air and ground transportation would also be curtailed during such conditions.

This system is unable to meet the imposed 60 minutes maximum security alarm response time - estimated response time to the furthest silo is two hours. However, this response time is far better than the response time that would be provided by a ground surveillance system traveling at 55 MPH. A significant decrease in the alarm response time would require a departure from mini-class RPVs to a fan jet

propelled model. This would significantly increase the acquisition, operation, and maintenance cost of the system.

Video system. The MINI-FLIR's only restriction would be during severe rain or snow storms. However, this restriction would apply to any human or electronic visual system. The MINI-FLIR far exceeds the other requirements.

Guidance and Control/Data Link/Ground Station. The ground station's multiple air vehicle control capability is limited by the number of RGTs in the system and their positions. However, a modification to the RGT is expected within the next five years that will allow the ground station to control up to eight RPVs simultaneously. All other requirements in this section have either been met or exceeded.

Costs. Table 4-1 is a cost comparison between the selected RPV system and a UH-1N helicopter system equipped with a MINI-FLIR. All costs shown have been converted to 1982 dollars utilizing the Consumer Price Index inflation figures of 8.9% for 1978, 12.9% for 1979, 12.6% for 1980, and 9.4% for 1981 and represents the costs associated with flying four RPVs and an equivalent number of UH-1N helicopters based on cruise speed and projected down time (36:2-3). This comparison is based on a 24 hrs a day operation.

The initial system acquisition cost is less for the UH-1N system, but once the training, operating, and maintenance costs are added in, the RPV system should be cheaper in the long run. Also, the RPV system acquisition cost allocation per RPV will decrease by approximately $922,853 once the multiple tracking modification is completed on the RGTs. The selected RPV system satisfies the cost requirements in Chapter II.

TABLE 4-1

SYSTEM COST SUMMARY AND COMPARISON

| COST ITEM | RPV SYSTEM* | UH-1N SYSTEM** |
|---|---|---|
| System Acquisition | $8,131,304 | $2,565,000 |
| Training | $96,000 | $4,929,224 |
| TOTAL | $8,227,304 | $7,494,224 |
| Operating and Maintenance | $9.58/hr | $ 327.54/hr |

*The RPV costs are based on a theoretical missile base that would require the use of eight RGTs and one GCS. This will allow a maximum of four RPVs to be airborne at one time due to the single RPV tracking limitations of RGTs. The operating personnel requirements are three shifts with four personnel per shift. The system acquisition cost includes the cost of 400 miles of buried cable. The number of RGTs and length of buried cable was established for cost comparison purposes only. The actual numbers required will vary considerably depending on the missile site terrain. The training cost represents the training of 12 operations personnel that is allocated equally among four RPVs. The RPV operating cost is based on the personnel costs of each shift, consisting of one captain with over four years in service and three staff sergeants with over four years in service, allocated equally among the four RPVs. We were unable to obtain an expected maintenance cost for the RPV system; however, based on the subsystems' high MTBF values combined with an estimated mean time to repair (MTTR) of .5 hr (derived from the Army's Tactical RPV Program), the expected maintenance costs would be low.

**The UH-1N helicopter system is based on the utilization of 3.8 UH-1N helicopters equipped with MINI-FLIRs. The 3.8 conversion factor results from the product of the cruise speed differential of .8, the projected down-time differential of 1.188, and the RPV force level of 4. The operational personnel requirements are three shifts consisting of two pilots (captains with over four years in service) per shift.

## Capabilities - RPV vs UH-1N

Table 4-2 is a comparison of the flight capabilities and restrictions between the proposed RPV system and the UH-1N helicopter system. The major differences between the two systems are their cruise speeds, their wind restrictions, their passenger capabilities, and their projected down-time. The UH-1N helicopter has a 20 MPH cruise speed advantage over the RPV system, but is also unable to satisfy the imposed 60 minute maximum security alarm response time--estimated response time to the furthest missile silo is 93 minutes. The UH-1N's wind restrictions are considerably better than the RPV's wind restrictions. As mentioned earlier, this is a serious drawback of the RPV system. The UH-1N's passenger capability is an important feature. This system could be manned with a security force that would be able to intercept intruders as soon as they are detected. However, this advantage in security force response time would have to be weighed against the added cost, personnel boredom, and loss of life risks that would be incurred. The RPV system has a major advantage over the helicopter system in its projected down-time. This will produce a more operationally ready force and reduce its life-cycle cost.

## Advantages/Disadvantages

Neither the RPV system nor the helicopter system are ideal for remote intrusion alarm assessment. An advantage of one system is not necessarily a disadvantage of the other system or vise versa. The advantages and disadvantages that surfaced during this study are listed below:

TABLE 4-2

FLIGHT CAPABILITIES/RESTRICTIONS SUMMARY

RPV AND UH-1N SYSTEMS

| CAPABILITY/RESTRICTION | RPV SYSTEM* | UH-1N SYSTEM |
|---|---|---|
| Cruise Speed | 80 MPH | 103.5 MPH |
| Range** | 333.3 miles | 289.8 miles |
| Ceiling | 10,000 ft | 15,000 ft |
| Wind Restriction - Track Off | 30 knots | 45 knots |
| Wind Restriction - Landing | 20 knots | 45 knots |
| Flight Temperature Restriction | above - below | above - below |
| Landing Visibility | 1/2 mile | 1/4 mile |
| Storm Restrictions | yes | yes |
| Projected Down-Time | .8%*** | 15 to 18% |
| Passenger Capability | none | 13 |

*The RPV's gross weight is 250 lbs (10 gals fuel/96 lbs instrumentation) which is at the vehicle maximum gross weight limits. The system capabilities are based on an airframe with a slightly larger wing span. Increasing the wing span will give a wing loading that would result in specifications equivalent to those given on page 22. Costs increases would be negligible (8; 37).

**The range of both systems can be increased if required. The RPV engine manufacturer stated that the RPV's range could be doubled by simply fine tuning the engine. The UH-1N helicopter's range can be increased by carrying additional fuel bladders in the passenger/cargo area.

***The RPV expected down-time is based on the system's estimated MTBF of 55.39 hours and MTTR of .5 hours.

RPV System.

Advantages

1. No risk of life from either the dangers of helicopter flight or adversaries who would probably be armed.

2. A lower system cost. The operating and support costs would be lower. The RPV system does not require highly skilled operating personnel as does the helicopter system. Thus, training costs and wages would be less. The maintenance would be less extensive. There would be less maintenance personnel and the maintenance actions themselves would be considerably less complicated. The maintenance facilities would be smaller in scale - a trailer rather than a hanger. Fuel consumption would be drastically lower, an important factor in today's fuel crisis.

3. Maintenance down-time for the RPV systems would be minimal. The bulk of the RPV system is electrical with high MTBFs. Parts can be replaced quickly and easily. No maintenance is required for human safety. When a system is down less, there are less operating units and spare parts required.

4. Because of its smaller size the RPV would not be as easily detected by intruders at the missile site. Even though, there is considerable propeller noise at cruising speed, the RPV still can make its initial surveillance relatively quietly. Since its ceiling is 10,000 ft, it can reduce power to an idle and glide from a distance to the loiter altitude.

5. One of the Security Police's problems is the boredom of a number of their assignments. This system would be operated by

the Security Police thus, they could offer selected personnel an interesting assignment.

6. There are no current operational DOD RPV programs. If this program became operational it could serve as a forerunner of other RPV applications.

Disadvantages

1. More than likely, this application would require RPVs to fly over public and private lands. There is uncertainty as to whether or not the FAA would allow RPV flight over such lands.

2. For the most part the XBQM-106 can fly in weather conditions that other aircraft cannot. However, the wind restriction of 20 knots (23 MPH) for recovery limits the RPV system for applications in high wind areas. This problem possibly could be resolved by a backup mode for emergency recovery.

3. RPV flight does not have the advantage of a person in the cockpit to handle unforeseen problems.

4. Recovery of a downed vehicle would be difficult due to its small size and the vast areas covered in flight.

5. The ground operations would be vulnerable to attack, the RGTs being the most susceptible. An adversary could easily disable the system by attacking one of the RGTs. However, under such circumstances any intrusion alarms would warrant justification to send out a fire team.

Helicopter System.

Advantages

1. The helicopter is a manned operation. The crew members can make judgments about unforeseen problems. Under certain conditions a helicopter can land near the site and deploy one or more troops who could detain the intruders until the fire team arrives.

2. The helicopter approach is a proven system.

3. The helicopter can be used for other missions when not on security alarm assessment. They could transport essential personnel, supplies, and equipment where needed.

Disadvantages

1. Higher system cost. Higher operating and support costs as opposed to those covered in the RPV advantages.

2. Helicopter surveillance induces a risk of loss of life both from flight operations and adversary actions.

3. There are requirements for highly trained operating and maintenance personnel. Training of such personnel is costly and often times these people are in short supply.

4. A helicopter operation requires extensive maintenance facilities.

5. The ground base fleet being in one location would make it vulnerable to attack.

CHAPTER V

SUMMARY/CONCLUSIONS/RECOMMENDATIONS

## Summary

Over the years the existing ICBM sites have experienced an increasing number of security false alarms. This combined with possible basing modes with increased distances between silos indicates a need for a quicker, more survivable means of security alarm assessment than the current manned ground transportation mode. In response to this need, the authors attempted to answer the question? "Can an RPV system effectively assess intrusion alarms at remote missile sites at a cost less than that of manned helicopter assessment?" This question was reduced to the following research questions?

1. What requirements would have to be met by an RPV system to effectively assess missile silo intrusion alarms?

2. What are the capabilities of an RPV and UH-1N helicopter systems?

3. What are the costs of an RPV and UH-1N helicopter systems.

4. Is an RPV system a viable alternative to a UH-1N helicopter system?

Through a review of available literature and interviews of the experts in the RPV and nuclear weapons security fields, the authors have identified a list of RPV surveillance system requirements; proposed an integrated RPV system utilizing existing subsystems to meet the requirements; and compared the RPV system's capabilities and

costs to those of a UH-1N helicopter system. The proposed RPV system consists of the Air Force's XBQM-106 airframe and the Army Tactical RPV Program's MINI-FLIR, guidance and control, data link, and ground station systems.

The RPV system satisfies all of the identified requirements except the maximum security alarm response time, the multiple vehicle control, and the inclement weather requirements. The maximum security alarm response time of 60 minutes was imposed for this study simply as a reasonable target and is not considered a critical requirement since the UH-1N helicopter system was also unable to meet it. The multiple vehicle control limitation can be overcome through the use of multiple RGTs and is expected to be solved by an RGT modification within the next five years. The inclement weather restrictions include severe rain, snow storms, and maximum winds of 30 knots for take off and 20 knots for landing. The severe rain and snow storm restrictions would be present for almost any form of air or ground alarm assessment system. However, the wind restrictions would greatly reduce the RPV's operational readiness and are seen as the only major handicap of the proposed RPV system.

When compared to the UH-1N helicopter system several advantages and disadvantages were noted. The RPV system is easier to operate and maintain, offers less possibility of detection by intruders, does not risk human lives, and is cheaper than the UH-1N system when the overall costs of acquisition, training, operating, and maintaining were considered. The RPV's shortfalls are its high initial acquisition cost, its more stringent wind restrictions, its slightly

slower cruise speed, its inability to react to some unforeseen conditions since there is no man in the cockpit, its inability to transport a security force to the silo, and its possible flight limitations by the FAA.

## Conclusions

In response to the four research questions, the requirements have been identified; the RPV system's capabilities and costs have been identified; the UH-1N helicopter system's capabilities and costs have been identified; and the two systems have been compared. The result of this analysis suggests that the RPV system is capable of assessing intrusion alarms at remote missile sites when the weather permits at a cost less than a manned UH-1N helicopter system. However, the RPV system's weather restriction would necessitate the utilization of a manned ground mode system for security alarm assessment as a backup system. Such a backup system would be required for any airborne assessment system.

It does not appear to the authors that the potential costs savings of the proposed RPV system would be sufficient to compensate for the systems restrictions and problems associated with fielding a new system. The proposed RPV system is not considered a viable alternative to a manned helicopter system at this time. However, once the RGT modification to allow multiple vehicle control is completed, the system's acquisition cost allocation per RPV would be reduced by approximately $922,853. This cost savings would be sufficient to make the proposed system a viable alternative.

## Recommendations

This study has demonstrated that an RPV system is capable of remote missile silo intrusion alarm assessment with some weather restrictions and that it may be a cost effective system. Further analysis of the data link between the GCS and the RGT's is required to determine if there is a cheaper alternative to buried cable. Such an alternative may be a microwave system. A complete life cycle cost analysis of the proposed RPV system should then be accomplished utilizing a generalized Minuteman site scenario. The results should then be compared to the life cycle costs of various low cost manned aircraft equipped with a FLIR. A means of simultating missile silo intrusion alarm assessment is shown in Appendix B. This simulation can be used to approximate the total number of air vehicles required and their utilization rate for a given site scenario. The resulting life cycle cost analysis would determine if an RPV system is truly a viable alternative means of missile site intrusion alarm assessment.

APPENDICES

# APPENDIX A

# LIST OF ACRONYMS

| | | |
|---|---|---|
| ADT | = | Air Data Terminal |
| AFFDL | = | Air Force Flight Dynamics Laboratory |
| AFIT | = | Air Force Institute of Technology |
| AFR | = | Air Force Regulation |
| AFWL | = | Air Force Weapons Laboratory |
| ARA | = | Altitude Reference Assembly |
| ASD | = | Aeronautical Systems Division |
| CCTV | = | Closed-Circuit Television |
| DOD | = | Department of Defense |
| EMP | = | Electro Magnetic Pulse |
| FAA | = | Federal Aviation Agency |
| FCEP | = | Flight Control Electronics Package |
| FLIR | = | Forward Looking Infrared |
| GCS | = | Ground Control Station |
| ICBM | = | Intercontinental Ballistic Missile |
| IR/CCTV | = | Infrared Closed-Circuit Television |
| LFO | = | Light Fiber Optics |
| MTBF | = | Mean Time Between Failure |
| NASA | = | National Aeronautics and Space Administration |
| RGT | = | Remote Ground Terminal |
| RPV | = | Remotely Piloted Vehicle |
| SAC | = | Strategic Air Command |
| SMSB | = | Strategic Missile Support Base |
| SPO | = | Systems Program Office |
| SPSS | = | Statistical Package for the Social Science |
| TR | = | Training Report |
| Q-GERT | = | Queuing - Graphical Evaluation Review Techniques |

# APPENDIX B

# RPV FORCE LEVEL SIMULATION

CONCEPTUALIZATION

The problem to be solved is to determine the optimal number of operational RPVs that will provide a maximum average alarm assessment time of 60 minutes. This scenario can be effectively modeled by a multiple queue, multiple server Q-Gert computer model. Multiple runs of the model can be made while varying the number of RPVs to obtain an estimate of the average alarm assessment time for each RPV force level.

Conceptual Design

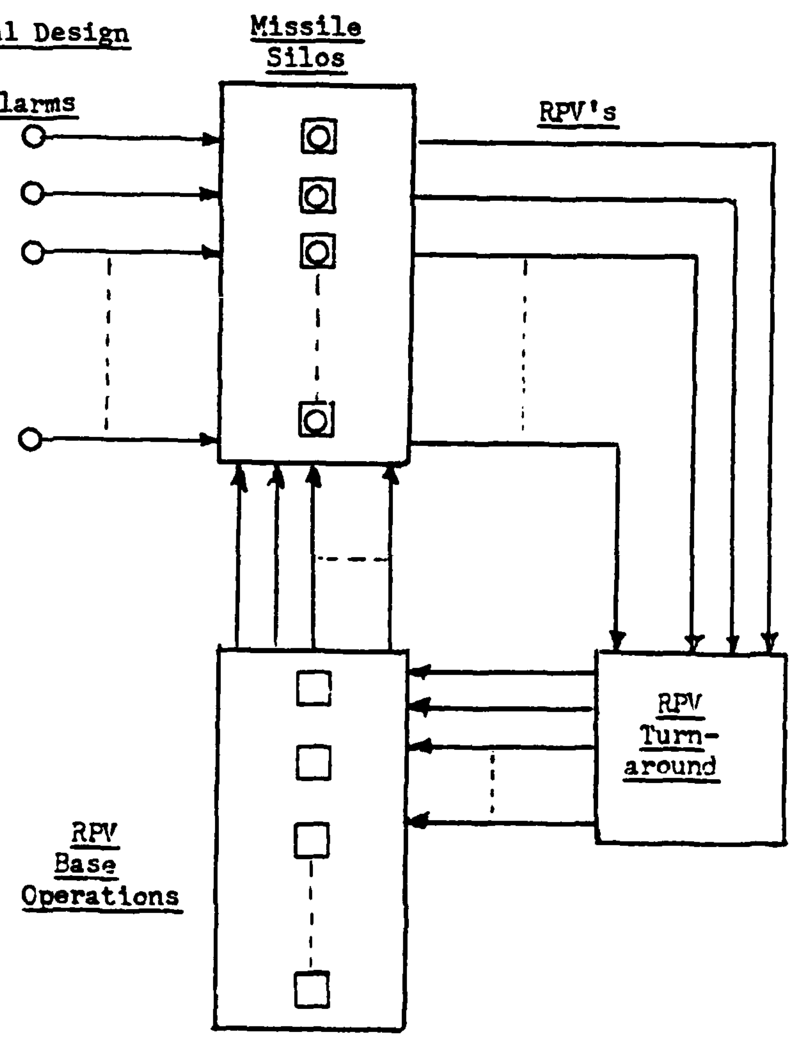


Figure B-1

## Design Description

This model simulates the arrival of intrusion alarms at ten missile silos, the dispatch of RPVs to assess the alarms, the alarm assessment, the return flights, and the turnaround preparations required to make the RPV's operationally ready. The missile silos are widely separated and encircle the RPV operations base. Each silo is approximately 50 miles from the base. Fuel limitations will not allow an RPV to assess alarms at more than one silo per sortie. The alarm rates are based on random draws from a uniform probability distribution with a mean of 20 alarms/day. When an alarm is received, one RPV equipped with a MINI-FLIR will be dispatched to assess it. A combination RPV flight time to the silo and loiter time at the silo will be randomly drawn from a normal probability distribution with a mean of 55 minutes, standard deviation of 10 minutes, maximum value of 75 minutes, and minimum value of 35 minutes. This is based on the RPV's cruise speed of 70 MPH, the 50 mile distance to the silo, the loiter time required at the silo, and the wind condition variances. A combination time for the return flight, refueling, preflight checks, and minor maintenance will be randomly drawn from a normal probability distribution with a mean of 80 minutes, standard deviation of 10 minutes, maximum value of 180 minutes, and minimum value of 60 minutes. The model accumulates time for each alarm from the moment it is received until an RPV has satisfactorily assessed it. Any alarms that are received at a particular silo that already has an alarm that has not been satisfactorily assessed will be ignored. The RPV can assess all outstanding alarms at a silo without increasing its flight

time. This will also prevent biasing of the mean alarm assessment times with unrealistically short assessment time. The individual alarm assessment times will be used to compute a mean assessment time for the run of 200 alarms. Four simulations will be run for each RPV for force level and an overall mean and standard deviation of each level will be calculated. This overall mean can then be used to select the minimum number of RPVs that will achieve a maximum mean alarm assessment time of 60 minutes. This will produce the minimum number of required operational aircraft needed. The expected number of aircraft that would be non operational for extended maintenance at any period of time will have to be added to this number to determine the total number of RPVs required to support the ten silos. The alarm rate and the RPV's flight times and turnaround times are general estimates and can be adjusted to fit a particular situation.

## QUANTIFICATION

### Computer Model

Figure B-2 is a Q-GERT flow diagram of the computer model.

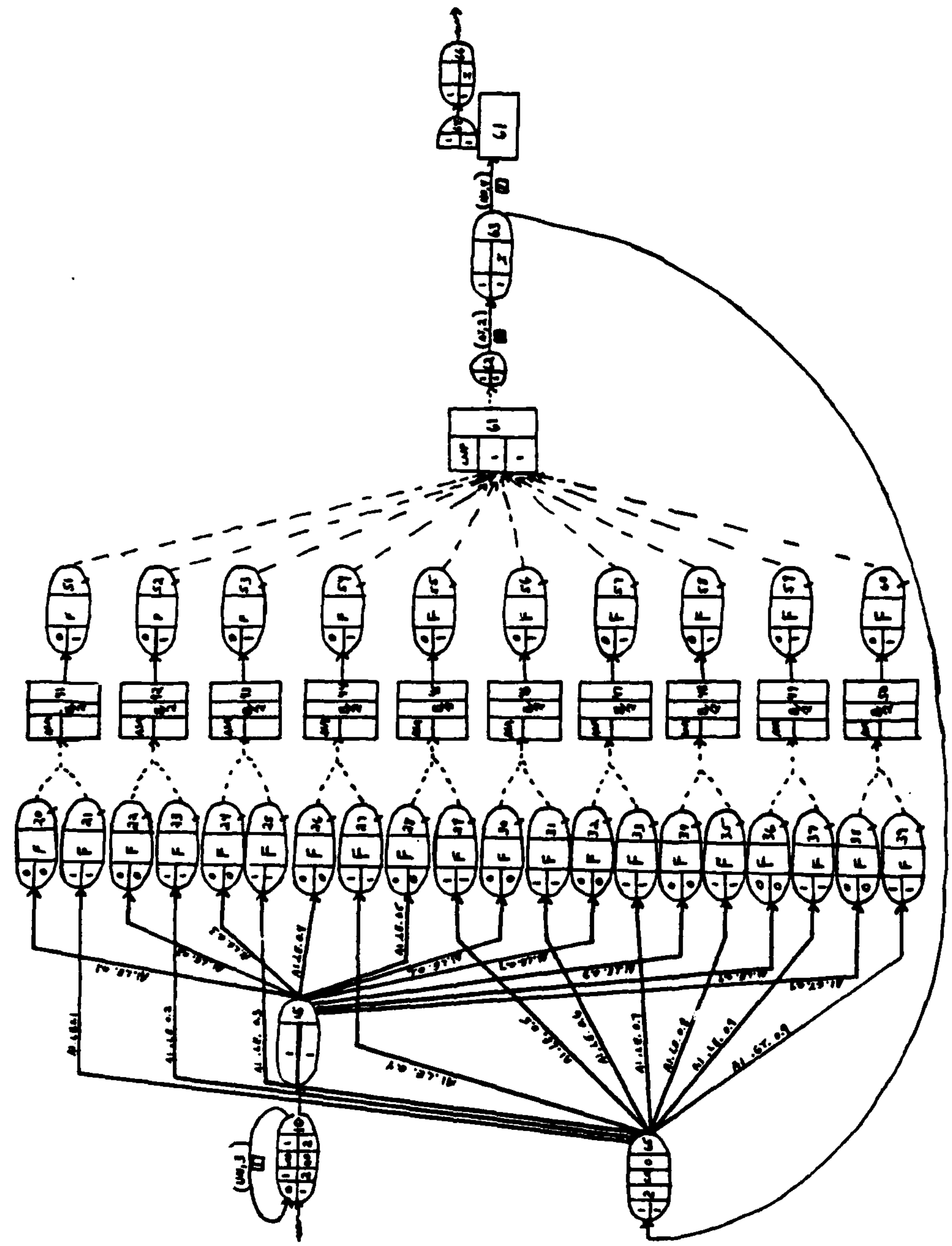

Figure B-2

*** INPUT CARDS ***

```
GEN,HARRIS,3,3,2,1982,1,1,200,,4,F,(14)2*
SOU,10,0,1,D,D*
VAS,10,1,UN,1,2,00,2*
REG,15,1,1,F*
QUE,20,0,0,D,F,(10)41*
QUE,21,1,1,D,F,(10)41*
QUE,22,0,0,D,F,(10)42*
QUE,23,1,1,D,F,(10)42*
QUE,24,0,0,D,F,(10)43*
QUE,25,1,1,D,F,(10)43*
QUE,26,0,0,D,F,(10)44*
QUE,27,1,1,D,F,(10)44*
QUE,28,0,0,D,F,(10)45*
QUE,29,1,1,D,F,(10)45*
QUE,30,0,0,D,F,(10)46*
QUE,31,1,1,D,F,(10)46*
QUE,32,0,0,D,F,(10)47*
QUE,33,1,1,D,F,(10)47*
QUE,34,0,0,D,F,(10)48*
QUE,35,1,1,D,F,(10)48*
QUE,36,0,0,D,F,(10)49*
QUE,37,1,1,D,F,(10)49*
QUE,38,0,0,D,F,(10)50*
QUE,39,1,1,D,F,(10)50*
SEL,41,ASM,,B/2,,20,21*
SEL,42,ASM,,B/2,,22,23*
SEL,43,ASM,,B/2,,24,25*
SEL,44,ASM,,B/2,,26,27*
SEL,45,ASM,,B/2,,28,29*
SEL,46,ASM,,B/2,,30,31*
SEL,47,ASM,,B/2,,32,33*
SEL,48,ASM,,B/2,,34,35*
SEL,49,ASM,,B/2,,36,37*
SEL,50,ASM,,B/2,,38,39*
QUE,51,0,1,D,F,(10)61*
QUE,52,0,1,D,F,(10)61*
QUE,53,0,1,D,F,(10)61*
QUE,54,0,1,D,F,(10)61*
QUE,55,0,1,D,F,(10)61*
QUE,56,0,1,D,F,(10)61*
QUE,57,0,1,D,F,(10)61*
QUE,58,0,1,D,F,(10)61*
QUE,59,0,1,D,F,(10)61*
QUE,60,0,1,D,F,(10)61*
RES,1/RPVS,2,61*
ALL,61,LWF,1,1,51/62,52/62,53/62,54/62,55/62,56/62,57/62,
58/62,59/62,60/62*
```

# of RPV's
Changed from 2 to 6.

```
REG,62,1,1*
STA,63,1,1,0,I*
FRE,64,0,1,1,61*
REG,65,1,1,F*
VAS,65,2,CO,0.0*
SIN,66,1,1,,I*
ACT,10,10,UN,3,1/ALARMS*
ACT,10,15*
ACT,15,20,(9)A1.LE.0.1*
ACT,15,22,(9)A1.LE.0.2*
ACT,15,24,(9)A1.LE.0.3*
ACT,15,26,(9)A1.LE.0.4*
ACT,15,28,(9)A1.LE.0.5*
ACT,15,30,(9)A1.LE.0.6*
ACT,15,32,(9)A1.LE.0.7*
ACT,15,34,(9)A1.LE.0.8*
ACT,15,36,(9)A1.LE.0.9*
ACT,15,38,(9)A1.GT.0.9*
ACT,41,51*
ACT,42,52*
ACT,43,53*
ACT,44,54*
ACT,45,55*
ACT,46,56*
ACT,47,57*
ACT,48,58*
ACT,49,59*
ACT,50,60*
ACT,62,63,AT,2,2/ENRT*
ACT,63,64,NO,4,3/RET*
ACT,63,65*
ACT,65,21,(9)A1.LE.0.1*
ACT,65,23,(9)A1.LE.0.2*
ACT,65,25,(9)A1.LE.0.3*
ACT,65,27,(9)A1.LE.0.4*
ACT,65,29,(9)A1.LE.0.5*
ACT,65,31,(9)A1.LE.0.6*
ACT,65,33,(9)A1.LE.0.7*
ACT,65,35,(9)A1.LE.0.8*
ACT,65,37,(9)A1.LE.0.9*
ACT,65,39,(9)A1.GT.0.9*
ACT,64,66*
PAR,1,,0.0,1.0*
PAR,2,55.0,35.0,75.0,10.0*
PAR,3,,0.0,144.0*
PAR,4,30.0,60.0,100.0,10.0*
FIN*

*** NO ERRORS DETECTED IN INPUT DATA ***

*** EXECUTION WILL BE ATTEMPTED ***
```

Alarm Rate
96, 144, and 288

## Research Design

The data points collected from the model represent the alarm assessment times averaged over a period of 200 alarms. Four data points will be collected for each RPV force level and three alarm rates--10 alarms/day, 20 alarms/day, and 30 alarms/day. The alarm rate variations are to provide a sensitivity analysis of the model. This will provide an indication of the increase/decrease in RPV force levels required for a 50% increase or decrease in the alarm rate of 20 alarms/day. The results will be listed in a table and plotted to provide a graphical representation of the system's response times. Also, an analysis of variance will be performed on the data points to determine if the variations in the Q-GERT data between configurations is due to the number of PRVs, the alarm rates, an interaction of the two, or due to error. A significance level of .01 will be used.

COMPUTERIZATION

## Data

The mean alarm assessment times for each run and a cumulative mean and standard deviation for each of the four run sets are shown in Table B-1.

TABLE B-1

| | | ALARM RATE | | |
|---|---|---|---|---|
| RPV's | | 10/Day | 20/Day | 30/Day |
| 2 | Run 1 | 59.75 | 81.67 | 205.35 |
| | 2 | 57.15 | 82.68 | 247.48 |
| | 3 | 58.74 | 86.57 | 226.23 |
| | 4 | 59.72 | 75.81 | 246.34 |
| | Mean | 58.84 | 81.68 | 231.34 |
| | Std. Dev. | 1.223 | 4.448 | 19.883 |
| 3 | Run 1 | 55.86 | 57.78 | 69.90 |
| | 2 | 55.82 | 62.66 | 71.66 |
| | 3 | 56.19 | 55.16 | 69.44 |
| | 4 | 54.95 | 63.60 | 77.42 |
| | Mean | 55.71 | 59.80 | 72.10 |
| | Std. Dev. | 0.528 | 4.008 | 3.668 |
| 4 | Run 1 | 55.36 | 55.52 | 55.68 |
| | 2 | 55.81 | 56.84 | 56.84 |
| | 3 | 55.57 | 54.07 | 56.94 |
| | 4 | 54.67 | 55.72 | 61.03 |
| | Mean | 55.35 | 55.54 | 57.62 |
| | Std. Dev. | 0.490 | 1.134 | 2.342 |
| 5 | Run 1 | 55.36 | 55.49 | 55.28 |
| | 2 | 55.81 | 55.30 | 55.66 |
| | 3 | 55.46 | 54.07 | 56.02 |
| | 4 | 54.67 | 55.14 | 55.60 |
| | Mean | 55.32 | 55.00 | 55.64 |
| | Std. Dev. | 0.477 | 0.632 | 0.304 |
| 6 | Run 1 | 55.36 | 55.49 | 55.28 |
| | 2 | 55.81 | 55.25 | 55.66 |
| | 3 | 55.46 | 54.07 | 55.93 |
| | 4 | 54.67 | 55.03 | 54.90 |
| | Mean | 55.32 | 54.96 | 55.44 |
| | Std. Dev. | 0.477 | 0.619 | 0.451 |

The cumulative mean alarm assessment times for each of the three alarm rates are plotted in Figure B-3.

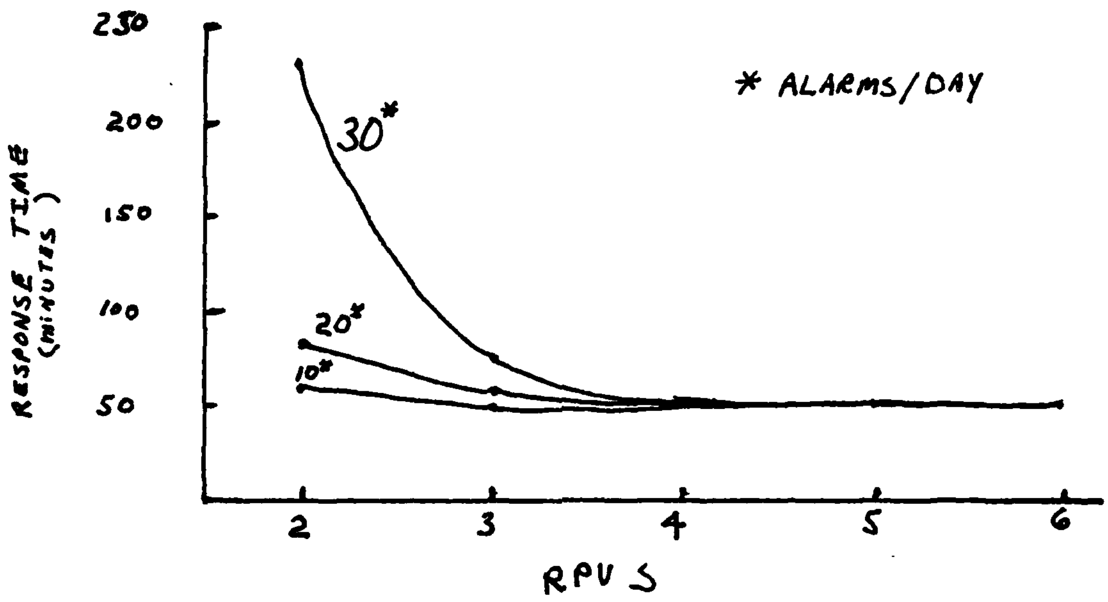


Figure B-3

## Verification/Validation

The alarm rates and RPV force levels have been varied and the model outputs have responded as expected. As the alarm rates increased, the RPV idle time decreased and the minimum number of PRVs required to produce an acceptable assessment time increased. For a given alarm rate, the mean alarm assessment time decreased and converged to a minimum value of approximately 55 minutes as the number of RPVs increased. This value represents the minimum mean alarm assessment time achievable when an RPV is always available for an incoming alarm.

An SPSS analysis of variance was performed on the Q-GERT data to determine if the variation in the data between configurations was due to the number of RPVs, the alarm rate, an interaction of the two, or due to error. A significance level of .01 was used. The following are the results of that analysis:

```
100=RUN NAME        RPV ANOVA
110=PRINT BACK      CONTROL
120=VARIABLE LIST   Y,A,B
130=INPUT FORMAT    FREEFIELD
140=N OF CASES      60
150=ANOVA           Y BY A(2,6),B(1,3)
160=READ INPUT DATA
170=59.76,2,1
180=57.15,2,1
190=58.74,2,1
200=59.73,2,1
210=81.68,2,2
220=82.68,2,2
230=86.57,2,2
240=75.81,2,2
250=205.36,2,3
260=247.48,2,3
270=226.24,2,3
280=246.35,2,3
290=55.87,3,1
300=55.83,3,1
310=56.19,3,1
320=54.96,3,1
330=57.79,3,2
340=62.67,3,2
350=55.17,3,2
360=63.60,3,2
370=69.90,3,3
380=71.66,3,3
390=69.45,3,3
400=77.42,3,3
410=55.36,4,1
420=55.81,4,1
430=55.57,4,1
440=54.67,4,1
450=55.52,4,2
460=56.84,4,2
470=54.08,4,2
480=55.73,4,2
490=55.69,4,3
500=56.84,4,3
```

```
510=56.94,4,3
520=61.04,4,3
530=55.36,5,1
540=55.81,5,1
550=55.46,5,1
560=54.67,5,1
570=55.49,5,2
580=55.30,5,2
590=54.08,5,2
600=55.15,5,2
610=55.28,5,3
620=55.66,5,3
630=56.02,5,3
640=55.61,5,3
650=55.36,6,1
660=55.81,6,1
670=55.46,6,1
680=54.67,6,1
690=55.49,6,2
700=55.26,6,2
710=54.09,6,2
720=55.03,6,2
730=55.28,6,3
740=55.66,6,3
750=55.94,6,3
760=54.90,6,3
770=FINISH
```

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*

                          SUM OF                MEAN            SIGNI
F
SOURCE OF VARIATION      SQUARES      DF      SQUARE       F       OF
F

MAIN EFFECTS           60329.815       6 10054.969 331.321     .00
1
   A                   43076.390       4 10769.097 354.852     .00
1
   B                   17253.425       2  8626.712 284.258     .00
1

2-WAY INTERACTIONS     53588.553       8  6698.569 220.724     .00
1
   A         B         53588.553       8  6698.569 220.724     .00
1

EXPLAINED             113918.368      14  8137.026 268.123     .00
1

RESIDUAL                1365.667      45    30.348

TOTAL                 115284.035      59  1953.967
```

The above data indicates that the number of RPVs, the alarm rate, and the interaction of the two are significant factors in the variations of the observed mean alarm assessment times.

The alarm rates and RPV flight times are based on theoretical estimates. The probability distribution functions used for these estimates can be altered when applying this model to an actual scenario.

## Conclusions

Based on the three alarm rates and the maximum mean alarm assessment requirement of 60 minutes, the following RPV force levels would be selected: 2 RPVs (10 alarms/day), 3 RPVs (20 alarms/day), and 4 RPVs (30 alarms/day). A 50% increase/decrease in the alarm rate (20 alarms/day) caused a 33.3% increase/decrease in the required RPV force level.

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